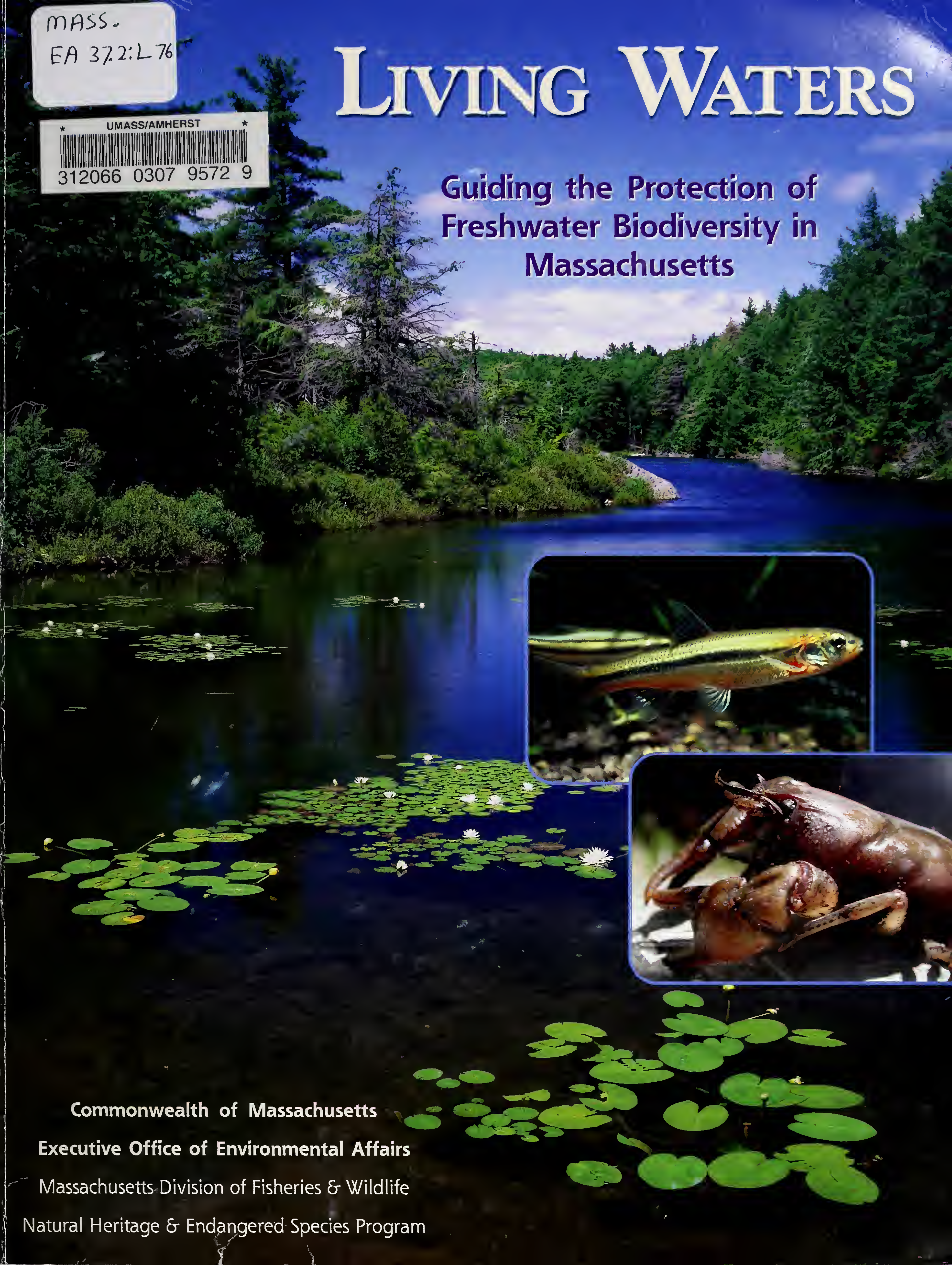
Living Waters

Guiding the Protection of Freshwater Biodiversity in Massachusetts



Commonwealth of Massachusetts

Executive Office of Environmental Affairs

Massachusetts Division of Fisheries & Wildlife

Natural Heritage & Endangered Species Program

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Back cover photo: Harvard Pond

LIVING WATERS

Guiding the Protection of Freshwater Biodiversity in Massachusetts

A project of the
Executive Office of Environmental Affairs
Ellen Roy Herzfelder, Secretary

Produced by the
Natural Heritage & Endangered Species Program
Massachusetts Division of Fisheries and Wildlife

Dear Friend of the Environment,

Water flows through our rivers and streams and fills our lakes and ponds. Rainfall percolates down through the earth, filling our aquifers and replenishing one of the basic resources of life. Water is the cornerstone of our ecosystems. Below the water's surface is a little-explored world with a diversity of habitats. These freshwater habitats are vulnerable throughout the Commonwealth. Aquatic ecosystems are threatened by pollution, by habitat destruction, and by the overuse of resources. It is critical that we intelligently plan for the conservation of our aquatic ecosystems.

Within Massachusetts there is a great diversity of aquatic habitats ranging from cold, clear streams running down Berkshire hillsides, to the powerful Connecticut River rolling out to Long Island Sound, to the placid, sandy Coastal Plain ponds that dot Cape Cod. The biological diversity within our Living Waters is rich. Rare freshwater mussels, silvery-sided fish, lurking dragonfly nymphs, and aquatic plants whose flowers may peep above the water's surface are but a few examples. In order to protect the habitats of these and other species, we must identify our targets for conservation.

The Natural Heritage and Endangered Species Program has created the Living Waters conservation map to identify these targets based on 25 years of biological data collected on rare species and their habitats. This map complements Natural Heritage's BioMap, which highlights key terrestrial and wetland habitats for rare species and natural communities. Living Waters identifies "Core Habitats" critical for rare aquatic species – as well as exemplary habitats in our rivers, streams, lakes, and ponds, and then links these habitats to the critical portions of their watersheds.

Living Waters will prove to be an invaluable resource for the stewardship of Massachusetts' aquatic biodiversity as we implement Governor Mitt Romney's smart growth strategy. Please join me in protecting the Commonwealth's freshwater natural heritage.

Ellen Roy Herzfelder, Secretary of Environmental Affairs
Commonwealth of Massachusetts

Living Waters Summary

The inland waters of Massachusetts are home to an impressive variety of freshwater species. Our waters are teeming with underwater life, from fishes and aquatic plants, to freshwater mussels, crayfish, snails, aquatic insects, and more. Unfortunately, our activities on land and our use of water resources have led to the loss and degradation of many freshwater habitats, making freshwater ecosystems among our most threatened. For this reason, the Natural Heritage & Endangered Species Program developed the Living Waters project to identify and map the lakes, ponds, rivers, and streams that should be the highest priority for freshwater biodiversity conservation in Massachusetts.

The Living Waters conservation map is based on more than 600 records of rare freshwater species compiled by Natural Heritage over the last 25 years and updated through recent field work. Living Waters also maps some of our best freshwater habitats identified from other data sets on fish, aquatic insect, and aquatic plant communities in Massachusetts. The **"Core Habitats"** in Living Waters identify water bodies that contain these rare species and exemplary habitats. For each Core Habitat, Living Waters also outlines a **"Critical Supporting Watershed"** to highlight the upland and upstream areas that have the greatest potential to influence, positively or negatively, the species living in Core Habitats.

Protecting freshwater biodiversity is complex because the health of each freshwater habitat depends on the health of its upstream watershed. **By protecting and restoring natural vegetation adjacent to Core Habitats, and by improving our land and water resource management within Critical Supporting Watersheds, we can ensure that our freshwater species will thrive for many years to come.**

Living Waters Conservation Plan

Core Habitats identify:
- important habitats for rare aquatic plants and animals
- exemplary freshwater habitats

\+

Critical Supporting Watershed is: the portion of a Core Habitat's watershed with the greatest potential to sustain or degrade the Core Habitat ecosystem

- Living Waters Core Habitats include multiple sites for:
    - 23 rare aquatic plant species
    - 24 rare invertebrate species
    - 11 rare fish species
    - Exemplary habitats in rivers, streams, lakes, and ponds
- Statewide, Living Waters Core Habitats highlight over 1000 miles of rivers and streams and 247 lakes and ponds as priorities for freshwater biodiversity conservation.
- Critical Supporting Watersheds cover 1,380,000 acres of undeveloped and developed lands that need protection or careful management to ensure the ecological integrity of our freshwater Core Habitats.

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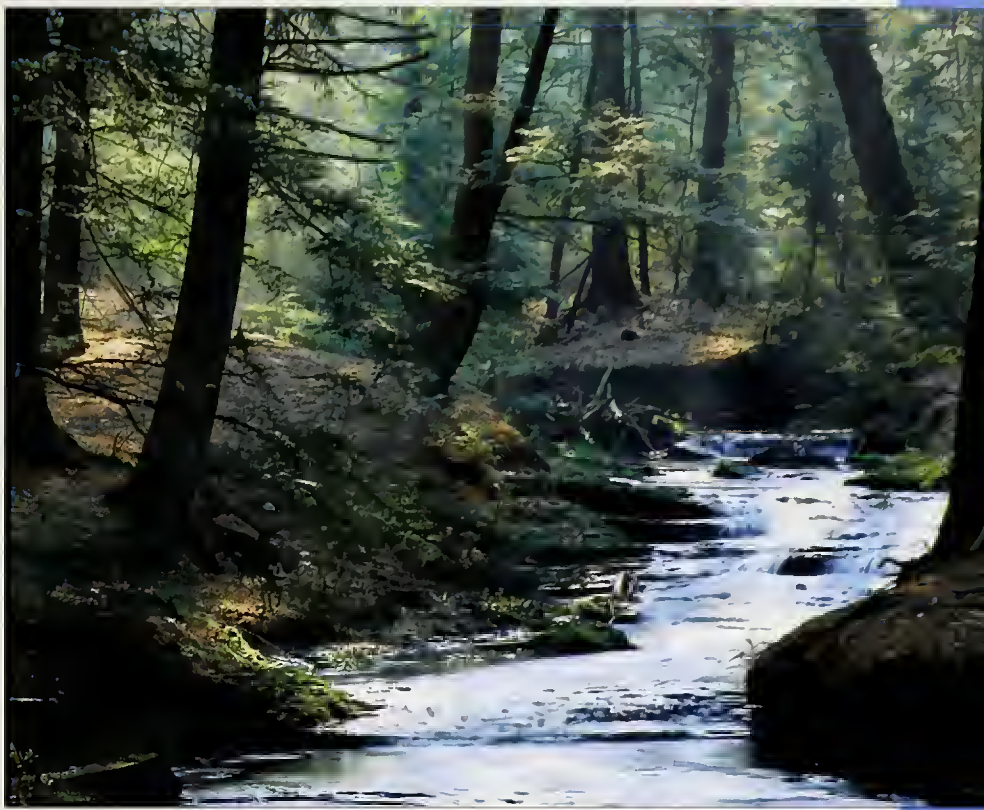


Introduction

For 25 years, biologists at the Massachusetts Natural Heritage & Endangered Species Program have been compiling, managing, and distributing biodiversity data on natural communities and rare plants and animals in the state. Natural Heritage tracks rare species as Endangered (the most imperiled), Threatened, or Special Concern. The biodiversity data is used to review the potential impact of development projects on state-protected rare species and habitats. The data also helps guide land management, ecological restoration, and land acquisition and protection.

Whether it is a familiar river winding through our neighborhood, or a favorite swimming hole, fishing spot, or tranquil view, the waters of Massachusetts provide us with a sense of place. Water is a critical resource for all life and it connects us to the natural world. Yet despite our dependence on water, most of us know little about the many animals and plants that live beneath the water surface.

From the small streams that rush down the hillsides of western Massachusetts to the mighty Connecticut and Merrimack Rivers, the Commonwealth contains a great number and variety of streams and rivers. Our lakes and ponds range from the mineral-laden "hard water" ponds in the Berkshires, to the depths of the Quabbin Reservoir in the central region, to the sandy shores of kettlehole ponds on Cape Cod.

This great variety of freshwater systems is home to a tremendous diversity of life. Massachusetts' waters are teeming with a wide array of fishes, aquatic plants, freshwater mussels, crayfish, snails, aquatic insects, and more. **Together these aquatic plants and animals make up the freshwater biodiversity of our streams, rivers, ponds, and lakes.** The lives of many aquatic species are intricately connected and interact in complex ways within their freshwater ecosystem.

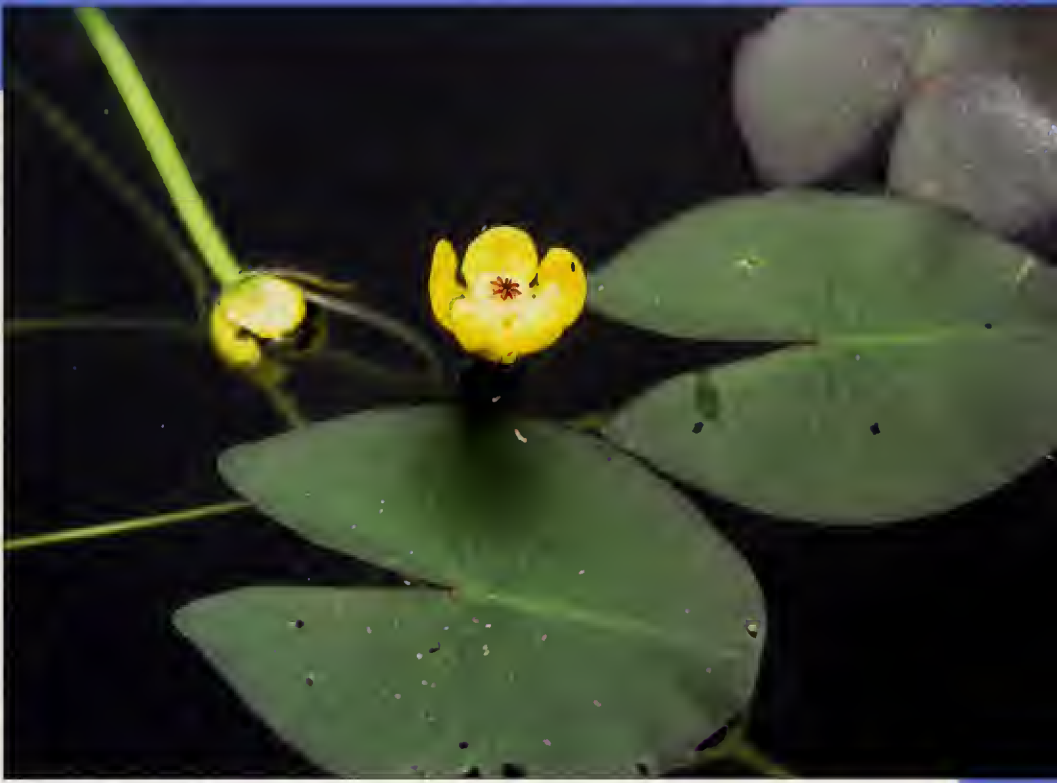
Healthy freshwater ecosystems provide some obvious, and many intangible, benefits to the local communities of Massachusetts. The same clean water required by aquatic organisms is also used as drinking water in many towns. Unpolluted stream corridors, lakeshores, and open waters provide recreational and aesthetic benefits to millions of Massachusetts citizens. A hiker who encounters an unexpected waterfall along a wooded trail, an angler who catches a native Brook Trout in a cool stream, or a child who swims and splashes in a local pond all experience the ways in which the protection of freshwater resources can enrich our lives.

The Living Waters Project

Humans tend to establish communities near water because of its great importance in our lives. Since European settlement, Massachusetts' waterways have experienced over 300 years of damming, diversion, water withdrawal, sedimentation, pollution, and exotic species introductions. These massive changes have resulted in the extirpation of sensitive freshwater species, such as the Trout-perch and the Virginia River Snail. Many other species like the Yellow Lampmussel, the Lake Chub, and the Tiny Cow-lily are at high risk of being driven to local or regional extinction. Fortunately, many aquatic species are resilient. Since the passage of environmental legislation like the federal Clean Water Act in 1972, the actions of citizens, governments, and industries to improve water quality and restore our waterways have helped freshwater species to persist.

The state of our freshwater biodiversity has reached a critical juncture. In the face of development pressure, ever-growing demands for drinking water, and potential climate change, we run the risk of satisfying our immediate needs at the expense of our biodiversity. **But if we educate ourselves, reform our water and land management practices, and become proactive about preserving the freshwater biodiversity of Massachusetts, we can ensure a legacy of biodiversity for future generations.** The additional benefits of conservation are that many of the same actions that save freshwater habitats will also help ensure that we have a fresh, clean water supply.

With support from the Executive Office of Environmental Affairs, the Natural Heritage & Endangered Species Program of the Division of Fisheries and Wildlife initiated the Living Waters Project to identify, map, and formulate conservation priorities for the diversity of freshwater plants and animals in



Tiny Cow-Lily *(Nuphar microphylla)*

Massachusetts. Living Waters is the culmination of two years' work by a team of biologists to identify critical aquatic habitats, or **"Core Habitats,"** in Massachusetts. The Core Habitats that are highlighted in Living Waters represent sites that are the most important for the preservation of freshwater biodiversity in Massachusetts based on our current knowledge.

Living Waters is intended for use with the Natural Heritage Program's recent **BioMap**. BioMap highlights conservation priorities for terrestrial species and many partially aquatic groups like rare salamanders, turtles, dragonflies, damselflies, water birds, wetland plants, and natural wetland communities. The BioMap is intended to help prioritize land protection opportunities in Massachusetts, while Living Waters should be used to guide management and stewardship of natural resources as well as inform land protection. Together, these two conservation guides identify key biodiversity sites in Massachusetts.

To get your copy of Living Waters or BioMap, contact Natural Heritage at natural.heritage@state.ma.us or 508-792-7270, Ext. 200.

Yellow Lampmussel *(Lampsilis cariosa)*

Exploring Life under Water

Living Waters highlights habitats in rivers, streams, lakes, and ponds for both rare plants and rare animals, as well as exceptional habitats for common aquatic species. Appreciating our great diversity of freshwater organisms in Massachusetts begins with an understanding of the differences between flowing and standing waters.

In streams and rivers, plants and animals have adapted to a high energy, dynamic environment. Gravity creates a one-way flow of water that carries sediments and nutrients from the narrow headwater streams down to the wide and meandering rivers. Forested headwater streams are shaded and cool and are replenished by groundwater (below ground water flow) and precipitation. Tiny crustaceans called amphipods can be found swimming at the streambed's groundwater interface. Other invertebrates like the larvae and nymphs of stoneflies, caddisflies, and mayflies live around the cobbles of the faster flowing stream riffles, while dragonfly nymphs prefer the quieter pools where water slows down and deposits leaves and sediments. The leaves and sticks that fall into a stream form the basis of the stream food chain as they are decomposed by fungi and bacteria and eaten by insect larvae and nymphs. Fallen trees create refuge habitats for fishes, such as Brook Trout, which feed on the aquatic insects.

The nymph of the **Primitive Minnow Mayfly** *(Siphlonurus)* breathes underwater through its delicate side gills.

As streams converge and widen into rivers, more sunlight penetrates to the streambed, supplying energy for aquatic plants and microscopic algae to grow. The addition of these food sources and an increase in habitat complexity provide many more ecological opportunities, or "niches," for different freshwater species. For example, mussels can get a foothold in the bottom sands and gravels where they filter the small organic food particles from the flowing river. With more invertebrates and plant matter for food, the number of small fishes increases, which in turn creates an opportunity for larger predatory fishes such as Chain Pickerel.

The environmental conditions in lakes and ponds are different from those of rivers and streams. Water moves more slowly and is retained longer, which can create greater habitat stability and lower the availability of oxygen. In the shallows of a lake or pond, groundwater is exchanged between land and open water through the bottom sediments. Aquatic plants are often rooted in these fine sediments where rich nutrients are available. Some fishes and invertebrates eat the plants and cycle these nutrients up the food chain. Aquatic plants also add important physical complexity under the water, providing essential habitats for algae, fishes, and invertebrates like snails, damselfly nymphs, and giant water bugs.

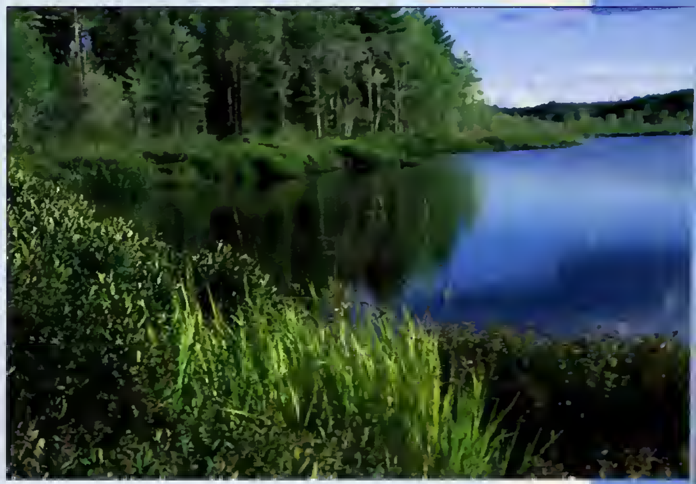
As a lake or pond deepens, sunlight does not penetrate enough for rooted plants to grow on the bottom. Tiny animals called zooplankton eat the microscopic algae that photosynthesize in the surface waters where sunlight is available. Open water circulates with the help of wind and changing water temperatures. Debris from the water and shore falls to the bottom of the pond where it is broken down by bacteria and invertebrates like non-biting midge larvae and aquatic worms.

The Watershed Connection

The water in a river, stream, lake, or pond originates from the surrounding uplands, which are collectively known as the watershed (see Figure 1). Water flows overland as runoff or percolates through the soil into the groundwater. The bedrock, soils, and vegetation affect the amounts and types of nutrients, sediments, and organic materials that move through the watershed to the receiving pond or stream. These materials determine whether a river's bottom is sandy or muddy, or whether a lake is acid or alkaline. In turn, the physical and chemical make-up of water bodies influences the species of plants and animals that live there.

Figure 1. Water from rain and snow melt seeps into the ground or flows overland into streams and ponds. In every watershed, surface water and groundwater flow downhill to a common point, like the river shown in this example.

The Value of Riparian Areas



Riparian areas are the swaths of land that border water bodies. A naturally vegetated riparian area acts as a "buffer" from the impacts of upland development, roadways, agriculture, and forestry operations. Although these areas only make up a small percentage of a watershed, they strongly influence the physical and chemical characteristics of water bodies and play a significant role in maintaining freshwater habitats.

Natural riparian vegetation shades and stabilizes the banks of streams and lakes. Plant roots help aerate the soil and allow it to absorb water during rainstorms, which slows overland runoff and minimizes soil erosion. Excess sediments have a harmful effect on freshwater habitats. They can bury the rocks and stones that are used by aquatic insects as attachment sites, the gravel that is vital for fish spawning and egg incubation, and the soft sands and gravels that anchor the fleshy, muscular "foot" of mussels. Shade from tree canopies helps maintain the cool water temperatures that enable water to hold oxygen. Many aquatic species need these high dissolved oxygen and low suspended sediment conditions to be able to breathe underwater.

Riparian vegetation also provides habitat and food for aquatic species. Overhanging shoreline vegetation serves as resting sites for emerging aquatic insects. Fallen trees and branches create shelter for fishes, egg-laying sites for insects, and well-oxygenated pools for filtering mussels. Invertebrates break down the trapped plant materials into smaller particles, which become a significant component of the aquatic food base.

Rare Species in Freshwater

Living Waters highlights Core Habitats for 58 rare species of fishes, aquatic plants, mussels, crayfish, snails, and other invertebrates. Focusing conservation attention on the habitats of rare species helps protect other species in the same habitats. Because rare species occupy a variety of habitat types, we can broadly protect Massachusetts' freshwater biodiversity. Protecting rare species is also important because these vulnerable organisms can be good indicators of the condition of freshwater systems that are highly valued by humans for their resources, aesthetics, and recreational opportunities.

Some freshwater species are rare because they are adapted to uncommon or localized habitats, or they have limited dispersal capabilities. For example, the rare aquatic plant Hill's Pondweed is adapted to hard waters and is only found in the western part of the state where marble bedrock creates mineral-rich conditions.

Other species are rare because they have decreased in numbers due to habitat destruction or overexploitation. Historically, pollution, overfishing, and the damming of rivers led to declines in our populations of Shortnose Sturgeon, which are now recognized as state- and federally-Endangered. Freshwater mussels and crayfish rank as the most imperiled species groups in the country. **More than fifty percent of Massachusetts' mussel species are considered to be at risk.** These sensitive filter feeders have a complex life cycle (see opposite page) and have been seriously depleted or eradicated due to dams, sedimentation, dredging, water withdrawal, and water pollution.

Freshwater species have not been as well studied as terrestrial plants and animals. They are hidden underwater, their habitats can be inaccessible, their taxonomy is often poorly known, and their distributions change through space and time. As a result, our baseline knowledge of many freshwater species is, at best, incomplete. In particular, the distribution of many freshwater invertebrate species is not well-known at all. This large taxonomic group encompasses freshwater sponges, nematodes, rotifers, mussels, snails, worms, leeches, crustaceans, insects, water mites, and more. Freshwater invertebrates are diverse and abundant. Much work is needed to fully understand this important component of biodiversity in Massachusetts (see Figure 2).

Taxonomic Group	Number of Rare Species[a]	Total Number of Native Species	Percent Rare in Massachusetts
Aquatic Vascular Plants	23	114	20%
Fish	11	57	19%
Mussels	7	12	58%
Aquatic Invertebrates	57[b]	>2500[c]	Unknown

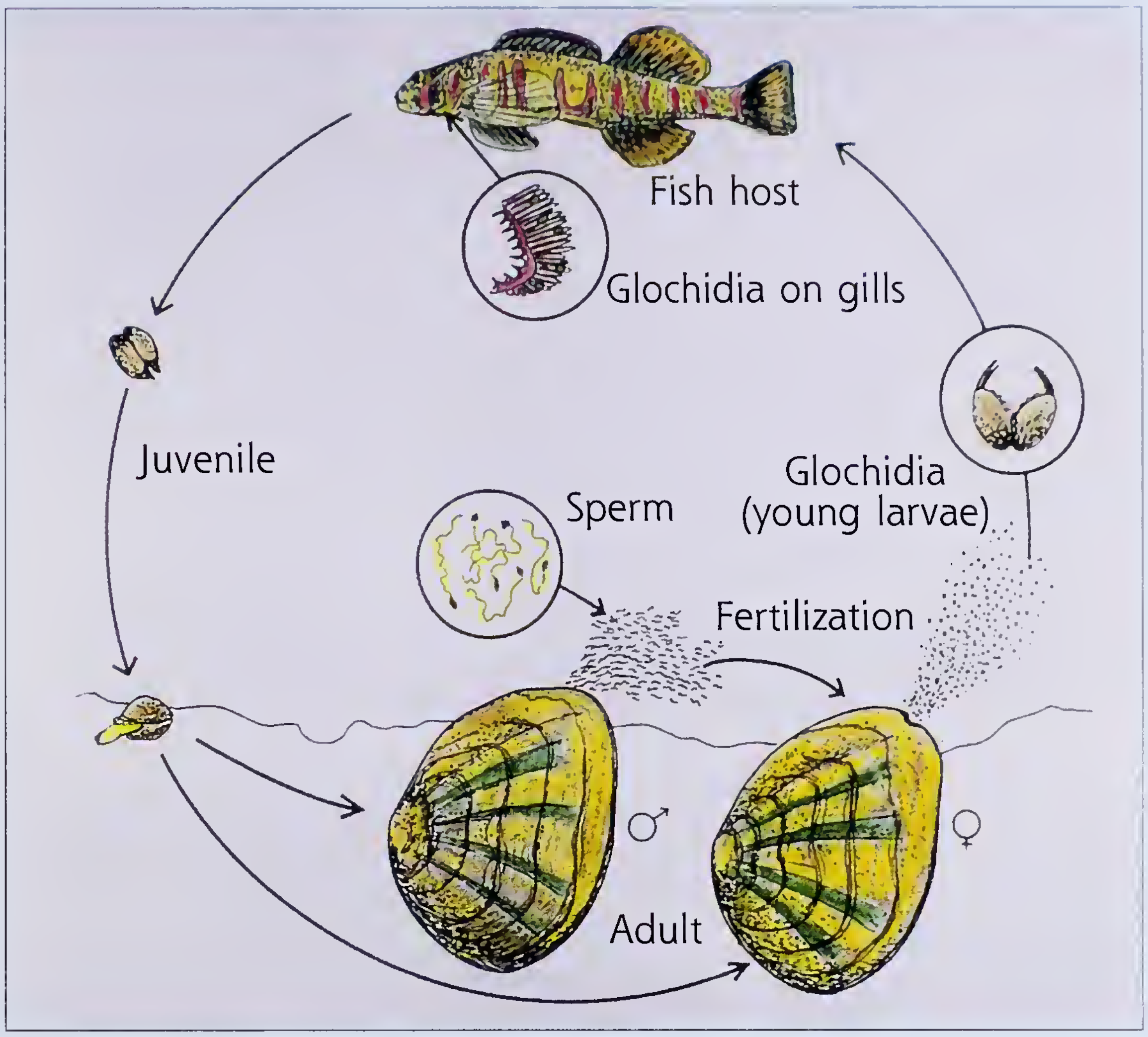
[a] Species that are state-listed as Endangered, Threatened, or of Special Concern or are 'watch listed' as potentially rare in Massachusetts.

[b] Includes rare damselfly and dragonfly species whose habitats were mapped in the BioMap.

[c] This estimate is based on our current knowledge, but the actual number of species may be much greater.

Figure 2. The status of freshwater taxonomic groups in Massachusetts.

The Life Cycle of Freshwater Mussels



Freshwater mussels anchor their foot in the bottom sands and gravels of many water bodies in Massachusetts. Their reproduction begins when male mussels expel sperm into the water column (right). Females siphon the sperm and their eggs are internally fertilized. Embryos are then brooded in the female's gills where, over time, they grow into larvae called "glochidia" (bottom left). Once the larvae are fully developed and environmental conditions are right, the female releases them into the water where they attach to the gills or fins of specific fish hosts. To improve the chances of finding a fish host, mussels have various adaptations to attract fish. Some mussels release groups of larvae in strands of mucous that resemble food for fish while others have fleshy mantles that look like minnows (bottom right). As fish attempt to prey upon these imitation food items, the larvae are released. During this parasitic stage, which is usually harmless to the fish, fish hosts provide nutrients and shelter that help larvae develop into juvenile mussels. This process is also the primary means of dispersal for the otherwise quite sedentary mussels. After several weeks of attachment, juveniles drop from their host and burrow into the substrate where, after several years, they will re-emerge as filter feeding adults to repeat this complex and amazing cycle. The freshwater mussel life cycle is just one example of countless fascinating life cycles that aquatic species have evolved to survive underwater.

Magnified view of a mussel larva, or glochidium

The **Yellow Lampmussel** *(Lampsilis cariosa)* has a fleshy mantle that resembles a minnow, which helps it attract a fish host

Threats to Freshwater Species

Across the nation, freshwater species are proportionally more imperiled than terrestrial plants and animals. Humans use rivers and ponds for drinking water, irrigation, power generation, transportation, and waste disposal. All of these uses greatly alter freshwater habitats. The three main threats to freshwater species are changes in water quantity, degradation of water quality, and the invasion of non-native species.

Since European settlement, more than 3000 dams have been built in Massachusetts. Even though virtually no new dams are constructed today, older dams continue to disrupt the natural flow of water. The combination of flow disruptions and large water withdrawals further degrades freshwater habitats by altering the natural fluctuations in the timing and availability of water (see opposite page).

The passage of the federal Clean Water Act in 1972 marked the beginning of focused efforts to reduce pollution from discrete sources such as power plants, manufacturing plants, mines, landfills, and sewage pipes. Although this law has successfully reduced the amount of pollutants now entering our waters, a few past "point source" polluters have left a toxic legacy at several sites. Toxic metals or organic chemicals like PCBs can remain in sediments and continue to affect the food web for many years after their initial release. Populations of freshwater species that were once obliterated by pollution have not become re-established in many cases.

Today some of the greatest threats to water quality arise from the cumulative impacts of human activities in the watershed. **This type of pollution is known as nonpoint source pollution because it originates from many diffuse sources that are difficult to pinpoint, and even harder to stop.** Agricultural and urban land uses often have a large nonpoint source impact on freshwater species. The collective runoff from agricultural fields may contain eroded soil, fertilizers, pesticides, and livestock waste. Stormwater from urban areas carries road salts, oils and greases, heavy metals, lawn fertilizers and pesticides, excess sediments, and septic system and pet wastes.

Perhaps the most recognizable result of nonpoint source pollution is the accelerated nutrient enrichment, or eutrophication, of water bodies. Excess nutrients upset the chemical balance causing excessive aquatic plant growth or algal blooms. This increased production of biomass builds up organic matter that decomposes and uses up the dissolved oxygen that would have been available to sustain other organisms. The resulting low oxygen conditions can have a deadly impact on aquatic species, as shown by winter or summer fish kills.

The invasive exotic plant, **Water Chestnut** *(Trapa na*

Disturbed conditions often promote the establishment of many generalist non-native plants, fishes, and invertebrates that have been accidentally or intentionally released in Massachusetts. Non-native invasive plants pose the biggest current threat, with 11 aquatic species known to be spreading across the state. These aggressive plants have few natural controls and in many settings may edge out native aquatic plants by using all of the available resources and physical space. They also alter the underwater structure of fish and invertebrate habitats and can contribute to oxygen depletion.

Changing the Course of Water

Heavy water use and drought in the Ipswich River Watershed have left the river's freshwater species with only a trickle of water in the summer.

Rivers are dynamic systems that fluctuate seasonally and during storm events. The amount, timing, and quality of water determine the shape of river channels, the types of habitat within a river, and the abundance and diversity of aquatic species. Riverine plants and animals have evolved to use changes in flow and water temperatures as cues to begin different life stages. These changes trigger fish and mussel spawning, the hatching of eggs, the dispersal of animal larvae, and the emergence of adult insects. In addition, natural flow variability creates constantly shifting habitats, which prevents dominance by any one species.

In the United States, only 2% of rivers remain free-flowing and relatively undeveloped. The more than 3000 dams in Massachusetts have altered natural river flows. These dams obstruct the general movements and spawning of fishes, as well as the dispersal of larval fishes, insects, and mussels. The reservoirs behind dams can increase water temperatures, remove fine sediments from the water, create habitats for generalist species, and promote the invasion of non-native species. Downstream water temperatures are warmed or cooled depending on the depth from which water is released from the reservoir. Riverbeds are scoured downstream of dams, which removes the natural substrates. Ill-timed water releases can flood riparian areas when adult insects are emerging from the water.

Water withdrawals and land use changes are more insidious threats to natural river flows. The removal and pumping of surface and groundwaters for residential, agricultural, and commercial uses can leave rivers without enough water to support aquatic life. Water withdrawals also increase water temperatures by decreasing the cool groundwater inputs to rivers.

In developed areas, the natural infiltration of rain and snowmelt into the ground is stopped by the impervious surfaces of paved roads, parking lots, and rooftops. In the dry months of summer, this means there is little groundwater to sustain flows in rivers. During storms, water quickly runs off impervious surfaces and into storm drains, picking up pollutants along the way. During heavy storms, the sheer volume and power of direct stormwater inputs erodes stream banks and degrades aquatic habitats.

Dam removals, water conservation, improved stormwater management, and mitigating the effects of impervious surfaces will begin to address these sources of flow alterations in our rivers. Only by minimizing their impact will we be able to protect the freshwater biodiversity of Massachusetts.

assachusetts has 3,000 dams, many of which
ere built before 1900 for water supplies,
dustrial mills, power generation, and recreation.

The Living Waters Approach

Mapping Core Habitats

For a detailed description of the methods used in the Living Waters Project, please refer to the Living Waters Technical Report available at www.state.ma.us/dfwele/dfw/nhesp or by request from the Natural Heritage & Endangered Species Program.

The Living Waters conservation plan consists of Core Habitats and their Critical Supporting Watersheds. The Core Habitats represent either habitats for rare freshwater species or exemplary freshwater habitats. The Critical Supporting Watersheds depict the upstream and upland areas that have the greatest potential to affect the health of the Core Habitats and should, therefore, be the highest priority for conservation and management efforts such as land protection and resource stewardship.

Rare Species

To assemble the Living Waters plan, Natural Heritage biologists set out to update and improve our understanding of rare freshwater species in Massachusetts. Biologists met with experts from across New England, searched herbaria and museum collections for known rare species locations, and collected and organized existing biological datasets. Following this initial detective work, biologists planned extensive surveys and took to the field in search of these rare and often elusive species (see Figure 3). These updates have been incorporated into the Natural Heritage conservation database that now houses over 600 current records of rare freshwater fishes, plants, and non-insect invertebrates such as mussels, snails, and amphipods.

With this updated information, biologists mapped rare species habitats. The Core Habitats that were delineated represent freshwater habitats that are important for the growth and reproduction of each rare species. Biologists mapped all known sites for rare species that are listed under the Massachusetts Endangered Species Act as Endangered or Threatened because of their critical status. For species that are state-listed as Special Concern or are on the unofficial watch list, biologists evaluated the occurrence data and surrounding landscape context before mapping their habitats. Using information on habitat preferences and life histories of each target species, biologists finalized the spatial extent of the Core Habitats.

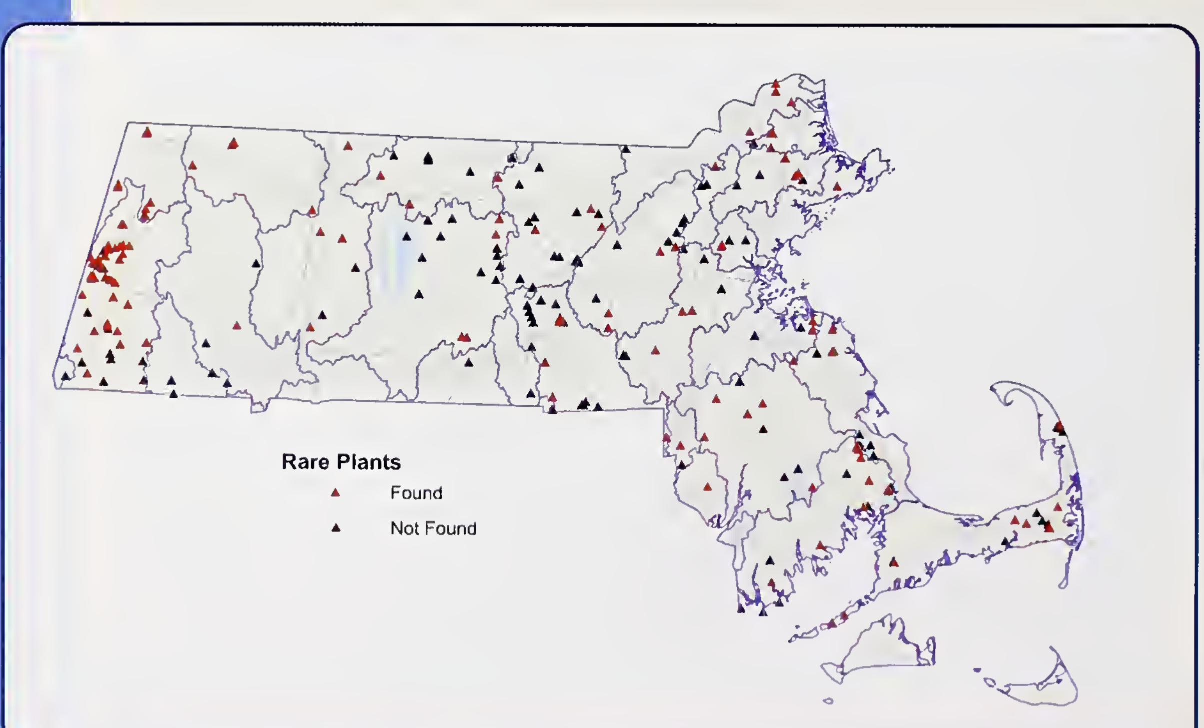


Figure 3. This map illustrates the water bodies searched for rare plants in Massachusetts since 1977, compared to those where rare plants were found and mapped as Core Habitat. During the Living Waters Project, biologists searched 151 lakes, ponds, rivers, and streams across the state for rare plants. While 57 of these water bodies were found to support rare aquatic plants, th remaining sites did not. Biologists suspect nutrient enrichment has caused some rare plant species to be out-competed by invasive and generalist species.

Exemplary Freshwater Habitats

In addition to the Core Habitats mapped for rare aquatic species, the Living Waters plan includes Core Habitats for a diversity of high quality aquatic habitats. Based on one or more combinations of biological data, water chemistry analyses, habitat evaluations, and natural landscape settings, these sites are presumed to support intact freshwater communities. This approach, termed the "coarse filter" approach, complements the species-based selection of conservation targets and helps to ensure that additional undocumented biodiversity is captured in the conservation plan.

Selecting exemplary freshwater habitats was a challenging task given that natural communities are not well defined for freshwater systems. The Natural Heritage staff developed a two-pronged approach to tackle this challenge.

The first method used a Geographic Information Systems (GIS) analysis to identify common types of streams and ponds occurring in natural settings. Biologists used aerial photographs and other data such as land use type or dam presence to create a final list of field sites across the state. At a subsequent site visit, biologists evaluated the landscape and aquatic habitat, and collected biological data to aid in an assessment of overall ecological integrity. For streams, the freshwater invertebrate communities formed the basis of this assessment (see below), while the species composition and abundance of aquatic plants helped inform the pond assessments.

A Living Waters biologist recently discovered this stonefly species (*Eccoptura xanthenes*), previously unknown in Massachusetts.

The second method supplemented the sites selected through the first method by evaluating readily available datasets from the Division of Fisheries and Wildlife, the Division of Marine Fisheries, the Department of Environmental Protection, the University of Massachusetts, the National Park Service, and many other organizations. Natural Heritage biologists used the fish, invertebrate, aquatic plant, and chemical information in these data sets to select and map important habitat types that are known to support portions of the state's freshwater biodiversity.

Invertebrate Communities and Stream Quality

A flowing stream has many invertebrate life forms that live together in a complex ecosystem. To identify conservation targets for Living Waters, biologists collected and examined communities of freshwater invertebrates in different types of streams to help assess the natural cycles of water, nutrients, and materials.

Invertebrates can be characterized by the way in which they ingest their food. "Shredders" tear leaf litter into small pieces, while "collectors" gather or filter small organic particles. "Scrapers" literally scrape algae, fungi, and bacteria off surrounding surfaces, and "predators" lie in wait to capture smaller invertebrates. For small streams, a high number of shredders suggests that the surrounding forest is supplying leaf litter to the stream, which in turn indicates that the link between aquatic and terrestrial realms is intact.

In addition, a large variety of invertebrates that is dominated by environmentally sensitive groups signifies a healthy stream. Many mayflies, stoneflies, and caddisflies are less tolerant of the conditions found in polluted or altered streams. A stream that contains a high percentage of these aquatic insects is likely minimally affected by human activities and therefore an important habitat for invertebrates and other freshwater organisms like fish.

Biologists disturb the stream bottom, which dislodges freshwater invertebrates into specialized "kick nets" for collection.

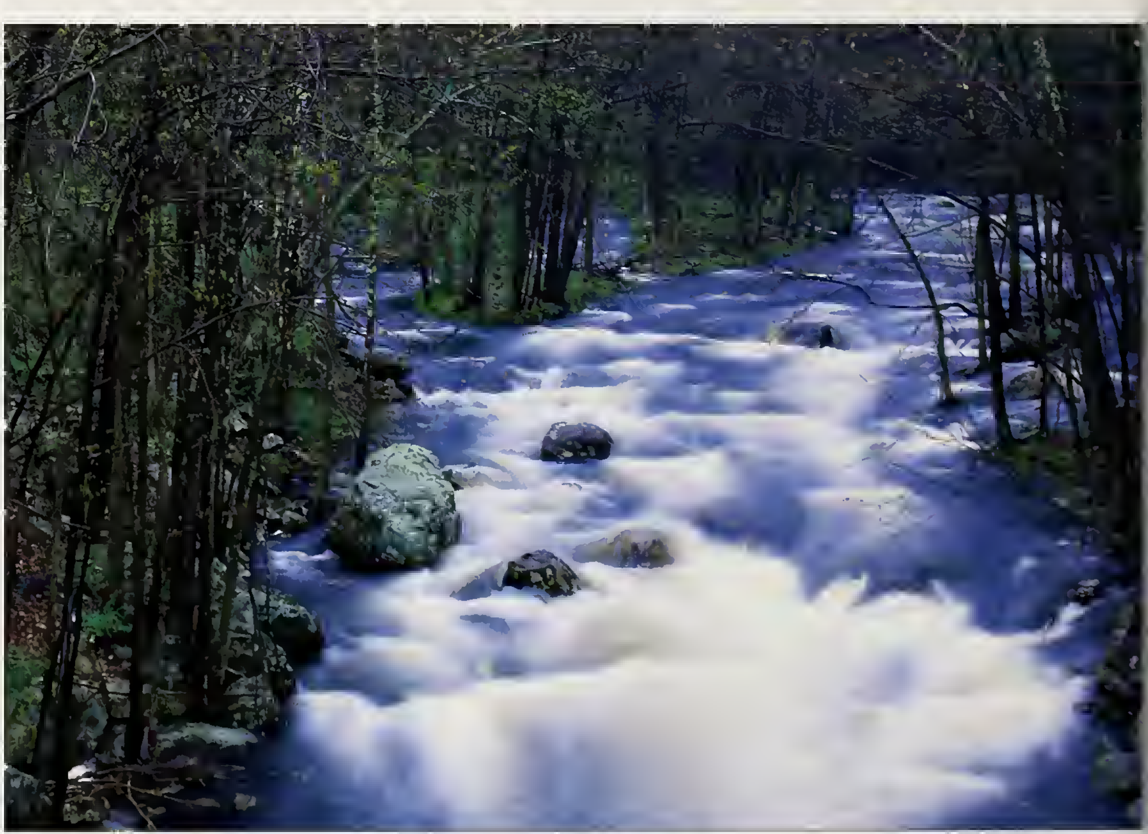
Critical Supporting Watersheds

The integrity of each Core Habitat depends on the health of its surrounding watershed, which makes protecting freshwater biodiversity a complex and wide-reaching task. In fact, most land in Massachusetts lies within the watershed of one or more Core Habitats. Therefore, conservation actions that improve the way we use land and water resources will most likely help protect Massachusetts' freshwater plants and animals.

To focus proactive conservation work, we developed the concept of a "**Critical Supporting Watershed**" that identifies the more immediate portion of a Core Habitat's watershed. The Critical Supporting Watershed represents the portion of the watershed with the greatest potential to sustain or degrade a Core Habitat (see Figure 4).

The boundaries of the Critical Supporting Watersheds were derived using a computer-based, Geographic Information Systems (GIS) model that was developed in collaboration with the Landscape Ecology group at the University of Massachusetts at Amherst. To delineate a given watershed, the model first calculates the directions of water flow based on the surrounding topography. Then, the model begins to define the Critical Supporting Watershed, starting at the perimeter of each Core Habitat and following the flow paths upstream and upland. The exact upstream and upland distances that the model delineates depend on the slope, the flow path, and the size of the stream or river. Based on the importance of riparian areas for aquatic habitat protection, the model was designed to create a Critical Supporting Watershed centered on the land adjacent to the Core Habitat and its upstream tributaries. The branched shape of many Critical Supporting Watersheds reflects these dendritic upstream networks.

Within each Critical Supporting Watershed, the GIS model calculated the amount of undeveloped land to help identify possible land protection targets. The model also used available data on dams, point source pollution, drinking water supplies, and land use to calculate several general measures of potential threats to Core Habitats. Within each Critical Supporting Watershed, the model estimated the amount of agricultural land, the percentage of impervious surfaces, the density of roads, the number of stream crossings, the number and types of point sources, the number of water supplies, and the amount of nonpoint source nutrient and sediment pollution. This coarse GIS analysis will help identify and prioritize initial conservation strategies that can be implemented in the Critical Supporting Watersheds to protect Core Habitats.



Flooding is an important natural process for exchanging nutrients and sediments with the floodplain and expanding the available freshwater habitat. This surging stream reminds us that all freshwater habitats are connected to the surrounding land.

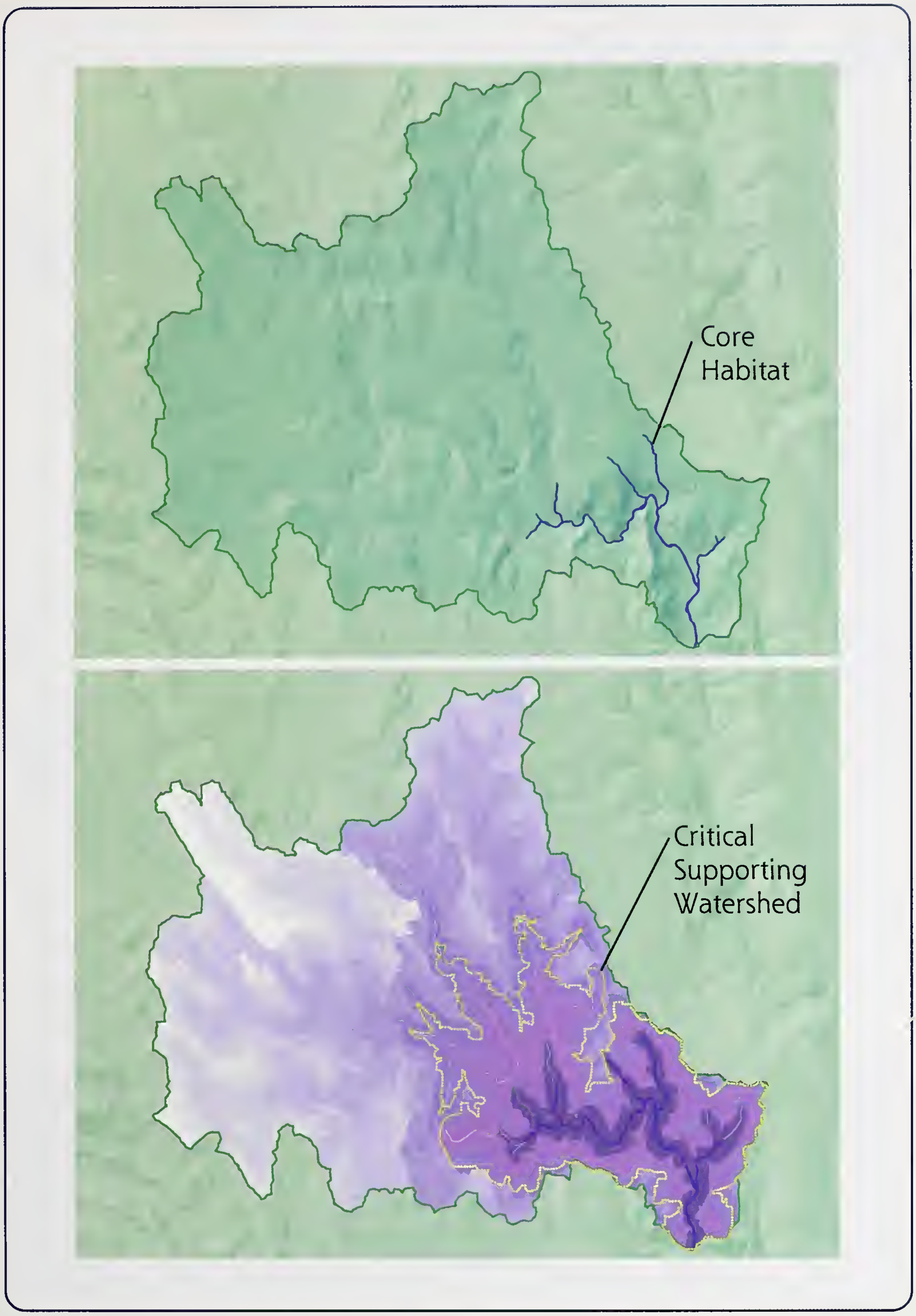
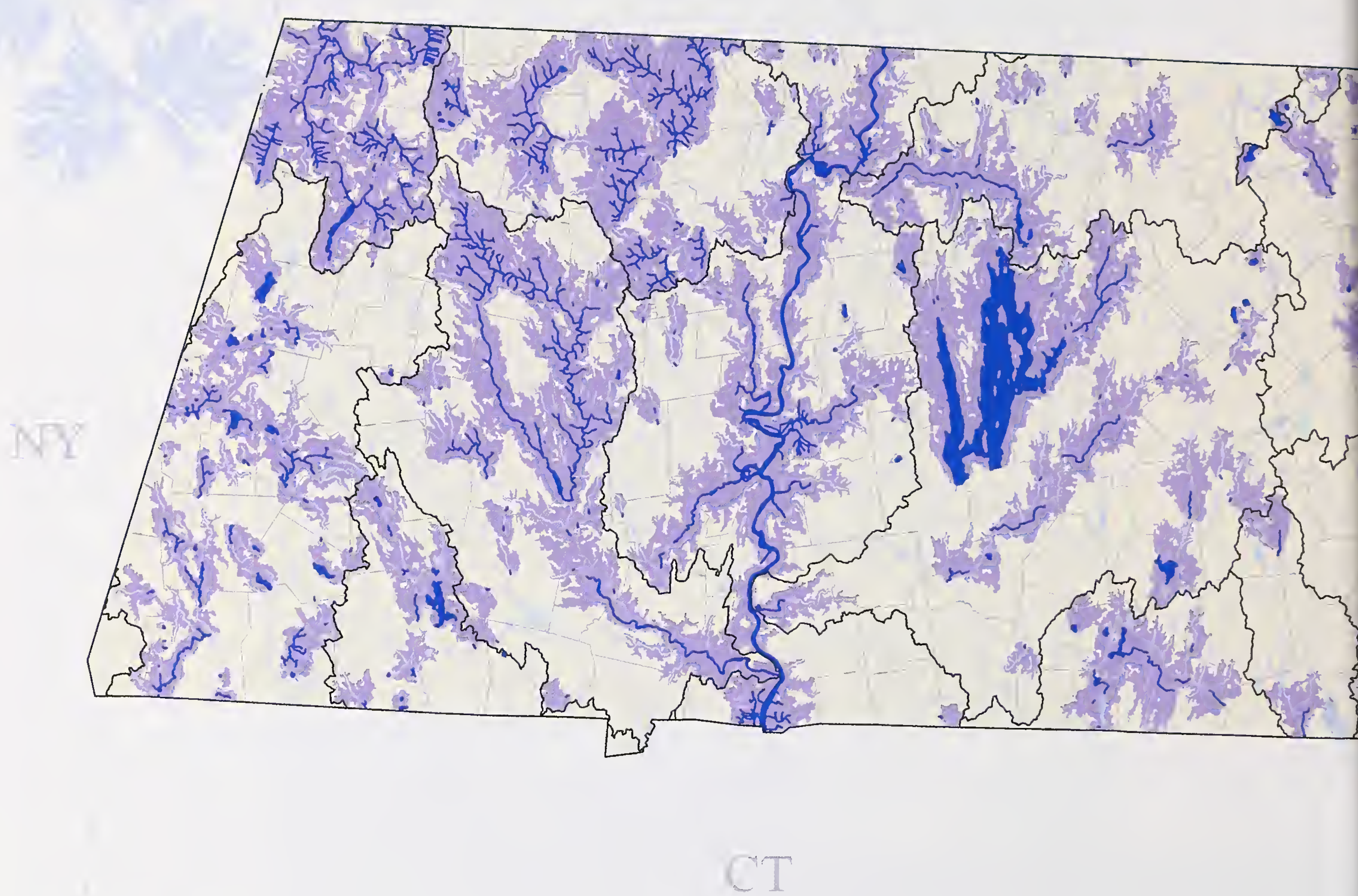


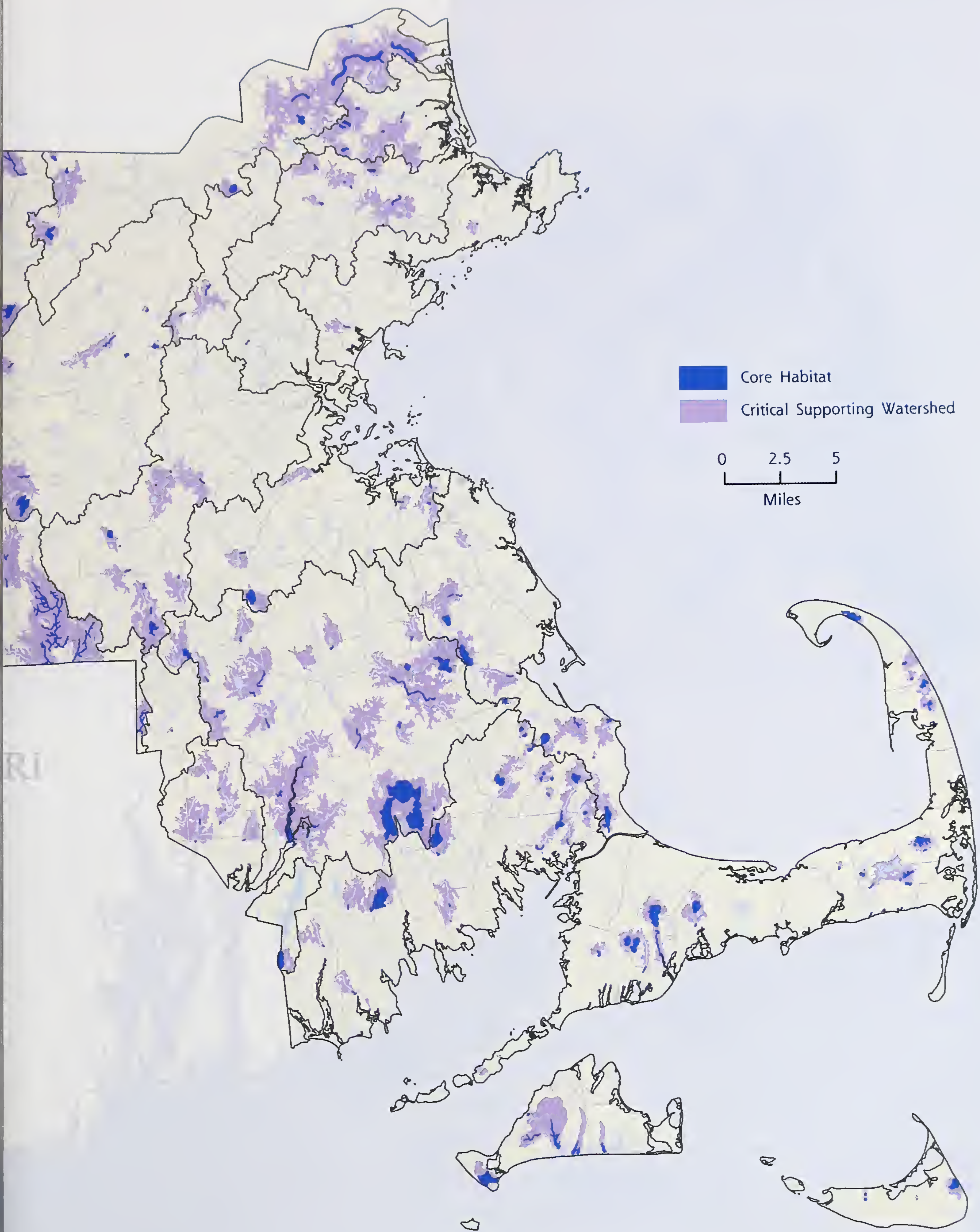
Figure 4. These graphics illustrate the concept of the Critical Supporting Watershed and its importance in protecting freshwater Core Habitats. A Core Habitat lies within the physical setting of its entire watershed (top). Within this watershed, the influence of the landscape on the Core Habitat diminishes farther away from the Core Habitat, as shown by the graded colors (bottom). Conversely, those lands nearest to the Core Habitat have the most influence on its biodiversity. The boundary of the Critical Supporting Watershed represents the area within which conservation actions, such as improved land management, decreased water use, and land protection, are likely to make the greatest contribution toward protecting the freshwater species living in the Core Habitat.

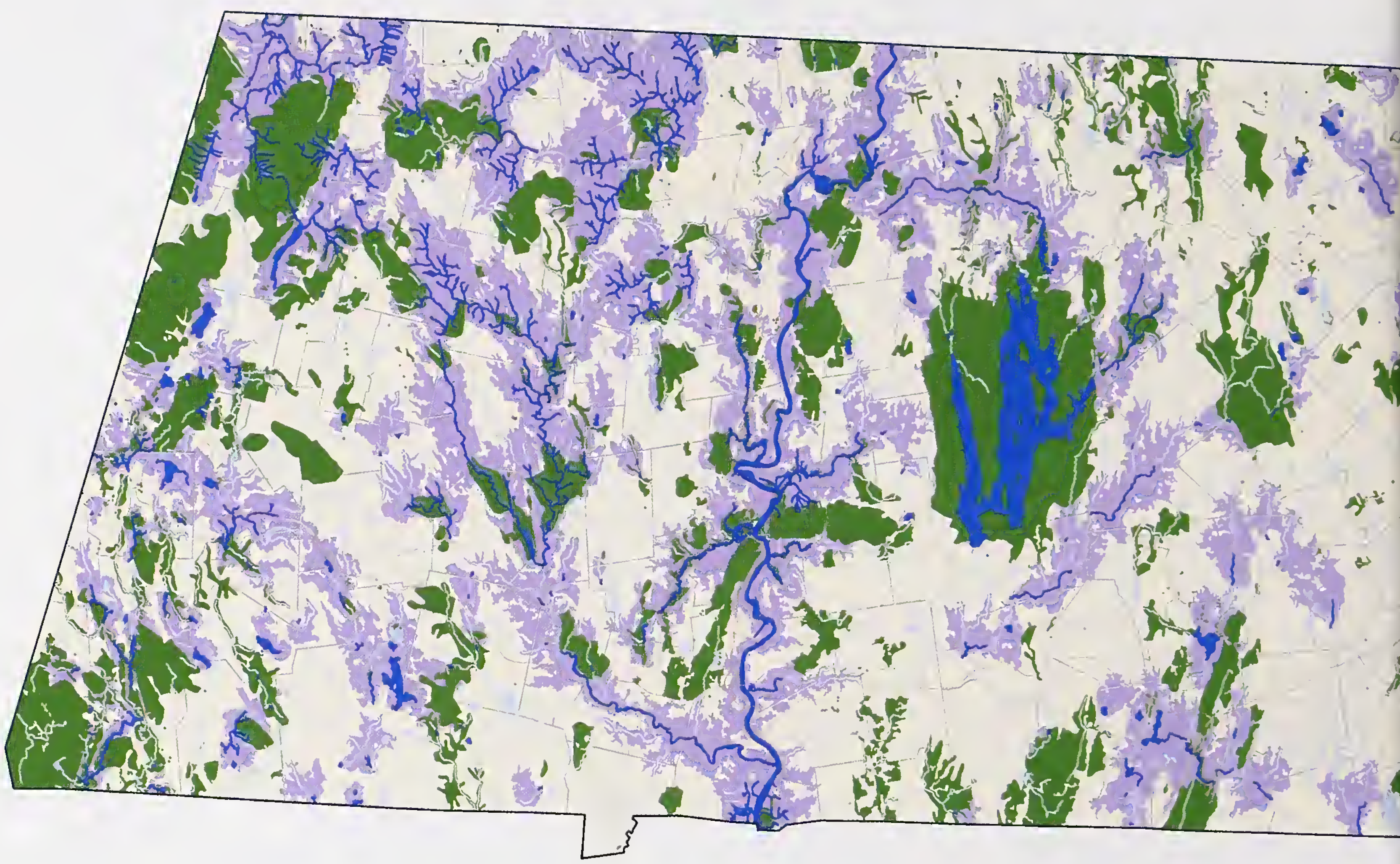
Living Waters



Core Habitats and their Critical Supporting Watersheds

The Living Waters map lays out a vision for conserving the state's freshwater biodiversity based on what is currently known about aquatic habitats and biodiversity in Massachusetts. Living Waters identifies 1000 miles of streams and rivers and over 200 lakes and ponds as the most important for the freshwater diversity of the state. Each freshwater Core Habitat represents either the habitat required by a rare species population or an exemplary aquatic habitat as determined from expert assessments of a site. The Critical Supporting Watersheds identify the portion of the watershed with the greatest potential to sustain or degrade the Core Habitats. The Critical Supporting Watersheds cover 27% of the state, and help to prioritize areas for land protection, watershed management, and ecological restoration.


Core Habitat
Critical Supporting Watershed
0 2.5 5
Miles



Living Waters and BioMap: Comprehensive Biodiversity Conservation

The Living Waters conservation plan complements the Natural Heritage Program's BioMap so that when used together, these plans highlight conservation targets for Massachusetts' non-marine biodiversity. Core Habitats in the two plans are of equal conservation priorities because they both identify critical biological habitats. Together, the Living Waters and BioMap identify 35% of the lakes and ponds, and 34% of the river and stream miles in the state as important for the protection of biodiversity.

The Supporting Natural Landscape in BioMap represents undeveloped land that buffers and connects BioMap Core Habitats and highlights additional unsurveyed habitats in the state. Critical Supporting Watershed should be interpreted differently because it highlights the watershed area, both developed and undeveloped, that influences each freshwater Core Habitat. These two distinct concepts arise from the different approaches necessary for aquatic and terrestrial conservation.


Living Waters Core Habitat
BioMap Core Habitat
Critical Supporting Watershed
0
2.5
5
Miles

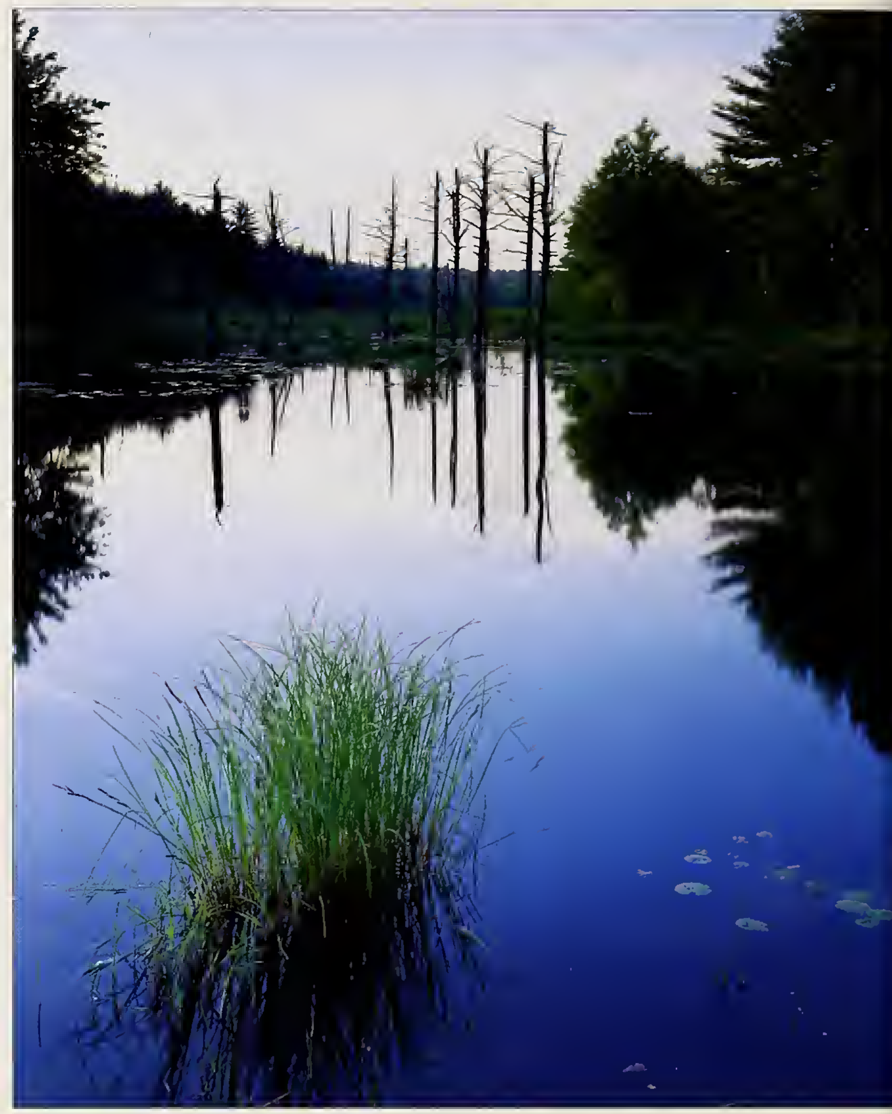
How to Use Living Waters

The Core Habitats and Critical Supporting Watersheds that are identified in the Living Waters plan outline conservation priorities for freshwater biodiversity. These sites are intended for proactive conservation work and may not identify all important rare species habitats or freshwater biological resources in the state. Instead, these areas are intended to help direct limited conservation funds toward known conservation priorities.

The boundaries of Critical Supporting Watershed do not distinguish between developed and undeveloped areas. Therefore, within each Critical Supporting Watershed, there may be varying opportunities for land protection, improved watershed management, and ecological restoration.

Land protection

To completely protect a Core Habitat, it would be best to avoid development in the Critical Supporting Watershed, or even in the entire watershed. However, many watersheds are too large for outright land protection, and are already moderately developed. In these cases, determining land protection priorities requires a strategic framework. Efforts should first be directed toward the immediate riparian areas of the Core Habitat, which are critical for the functioning of the aquatic ecosystem, and for pollution reduction in a developed landscape (see box). Once the immediate riparian areas have been protected, the riparian areas upstream of the Core Habitat should be considered for protection. Then the remaining areas in the Critical Supporting Watershed can be considered for land protection, with a greater emphasis on tributaries and land closer to the Core Habitat. For more information on this tiered approach, please contact the Natural Heritage & Endangered Species Program.



Riparian Areas as Priorities for Land Protectior

Naturally vegetated riparian areas are critical for maintaining healthy aquatic habitats and should be key land protection targets for aquatic conservation. Many streams and lakes in Massachusetts are intersected by roads or bordered by development, row crops, grazing areas, or well-maintained lawns. One rainstorm can flush salt, sand, fertilizers, pesticides, and waste directly into rivers and lakes. Vegetated riparian areas act as "living filters" and can significantly decrease the amount of sediments, nutrients, and pollutants entering the water. The living, decaying, and dead vegetation in riparian areas intercepts pollution-laden runoff, slowing it down and allowing it to permeate through porous soil. Once in the soil, bacteria, microorganisms, or biochemical processes can break down pollutants, or plant roots can absorb them so that they do not enter the adjacent water bodies. **The protection of natural riparian areas today will help ensure that aquatic habitats are preserved for the future.**

Watershed Management and Restoration

In some cases, Core Habitats lie within or near urban or agricultural areas such that land protection in the Critical Supporting Watershed must be supplemented with ecological restoration or the implementation of "best management practices," known as BMPs.

Core Habitats surrounded by agricultural lands can experience runoff from row crops containing soil, fertilizers, and pesticides. Farmers can avoid or minimize these releases by practicing conservation tillage, testing soils to determine the appropriate amount of fertilizer, and incorporating integrated pest management strategies that use little or no pesticides. Livestock can pose an additional risk to Core Habitats. Animals can trample and erode stream banks and their manure can further pollute streams and groundwater. Rotational grazing, fencing livestock away from streams and ponds, storing manure away from water bodies, and widening riparian buffers can minimize these impacts. There are several state and federal funding programs that help farmers implement these and other BMPs that protect freshwater habitats and drinking water quality.

Creating a watershed management plan focused on the Critical Supporting Watershed can help communities bring together town officials, industries, conservation groups, watershed associations, lake and pond associations, and private citizens. A watershed plan can help identify and develop strategies to address current and future point and nonpoint source pollution through planning, education, and management. For example, watershed-based zoning and land use planning by-laws can be effective ways to avoid pollution associated with stormwater runoff from impervious surfaces. Conservation groups can plan public education events, while local Departments of Public Works can implement regular street sweeping and catch basin cleaning programs to reduce sediment pulses during storm events.

These are just a few ways in which communities can work together to manage Critical Supporting Watersheds for the protection of both Core Habitats and important drinking water resources. Contact the Massachusetts Department of Environmental Protection for more information on pollution prevention or mitigation strategies for your town.

Dam removals help restore fish habitats and the natural flow of water and sediments in streams.

Reduce Your Impact on Freshwater Habitats:

- Conserve water and fix leaks
- Reduce household hazardous waste
- Landscape with native plants
- Make paths with porous surfaces
- Reduce lawn fertilizers and herbicides
- Clear invasive plants from boat motors
- Maintain your septic tank
- Preserve riparian vegetation
- Enjoy natural shorelines
- Become a watershed advocate

Living Waters by Watershed

Given the interconnections between terrestrial and aquatic ecosystems, the protection of freshwater biodiversity requires a watershed approach. The 27 major watersheds of Massachusetts provide a natural, holistic framework for looking at the Living Waters conservation plan in detail. For this report, the 27 watersheds were organized into 11 groups based on their biological similarities, geology, proximity, and flow directions (see Figure 6).

The amount of Critical Supporting Watershed that was delineated varies across the state (see Figure 7). The majority of land within the Critical Supporting Watersheds is currently undeveloped and unprotected, leaving the freshwater species in Core Habitats vulnerable to the impacts of further development. To help identify the relative magnitude of potential threats to Core Habitats, our GIS model for the Critical Supporting Watersheds compared six major threats among the 11 watershed groups. Although threats vary from one Core Habitat to the next, these relative ranks help illustrate which watersheds are most likely to be affected by different human activities (see Figure 5).

The following pages show Core Habitats and Critical Supporting Watersheds in the context of their surrounding waters, towns, roads, and protected open space. We give a brief description of the watersheds, followed by interesting highlights of the freshwater species living in, but not limited to, each watershed. We also provide summary information about the Core Habitats, which includes the amount of the adjacent **riparian area** (within 330 feet from the water's edge) that is protected as conservation land with relatively long-term legal protection. For the Critical Supporting Watersheds, we detail the types of land use and the number of potential threats to Core Habitats.

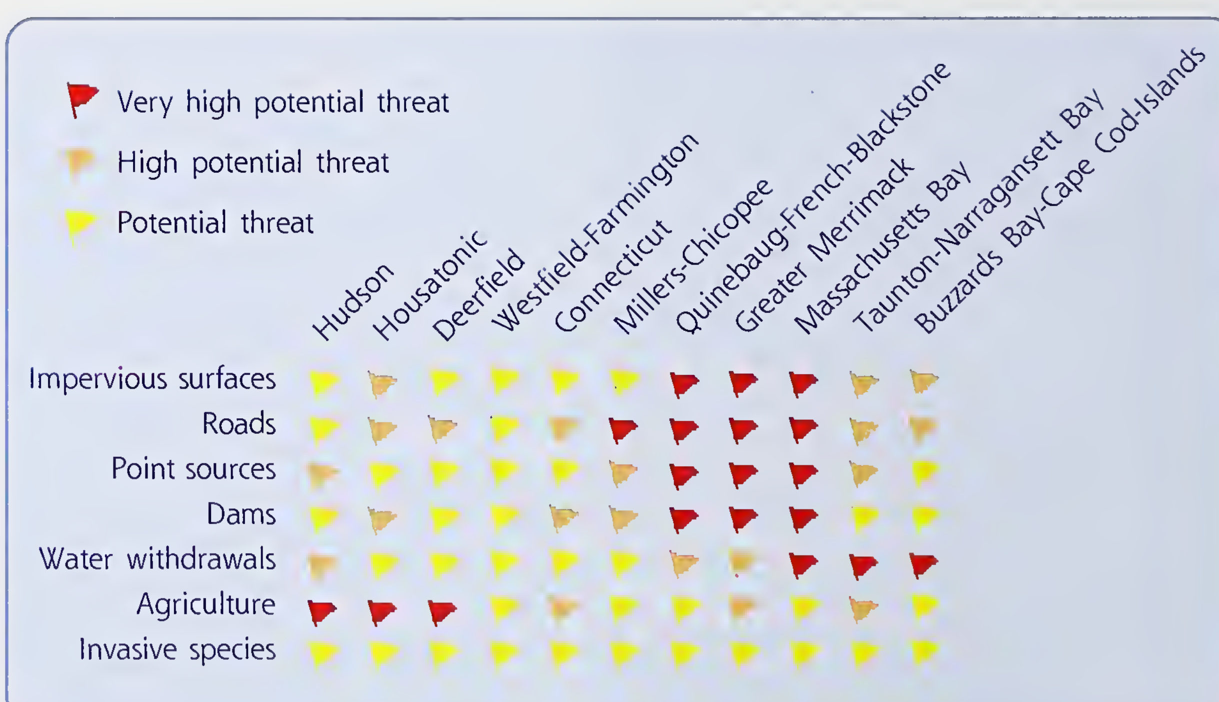


Figure 5. A relative comparison of six potential threats to Core Habitats across the 11 watershed groups. Red flags indicate the watershed groups that ranked the highest for a given threat. The relative ranks are derived from a GIS-modeled threat assessment that weighted potential threats in the Critical Supporting Watershed based on their proximity to Core Habitat. The threat of invasive, non-native species was not ranked because of the difficulty in quantifying this potential threat. For more information, see the Living Waters Technical Report.

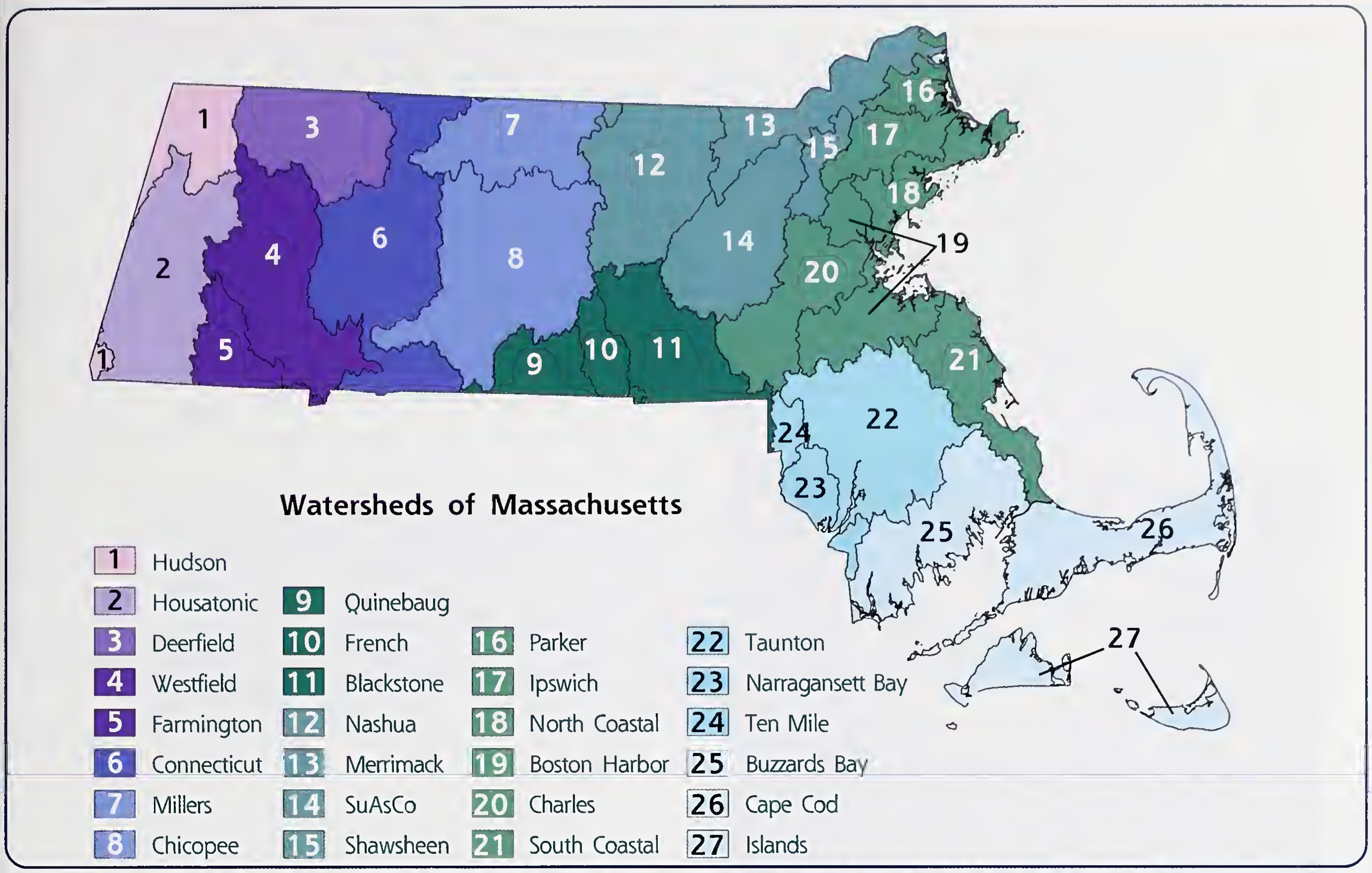


Figure 6. The 27 Major Watersheds in Massachusetts, as defined by the U.S. Geological Survey Water Resources Division and the Massachusetts Water Resources Commission. Watersheds with identical colors are discussed together in this report.

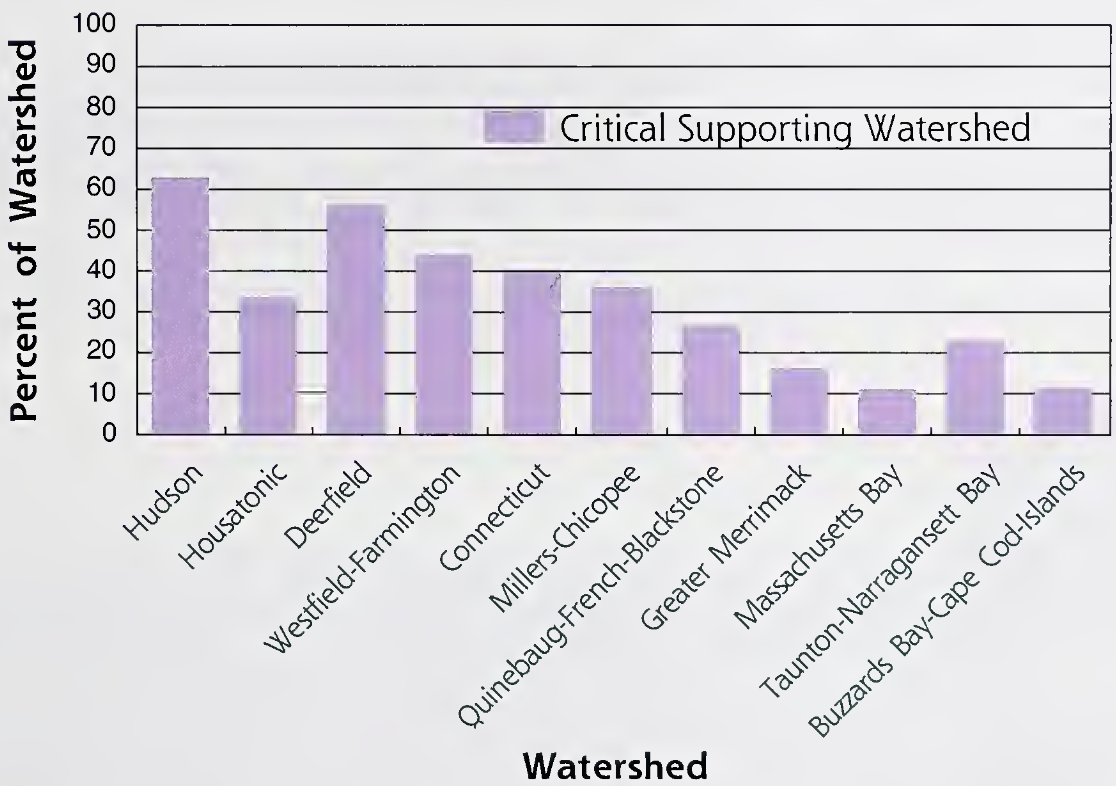
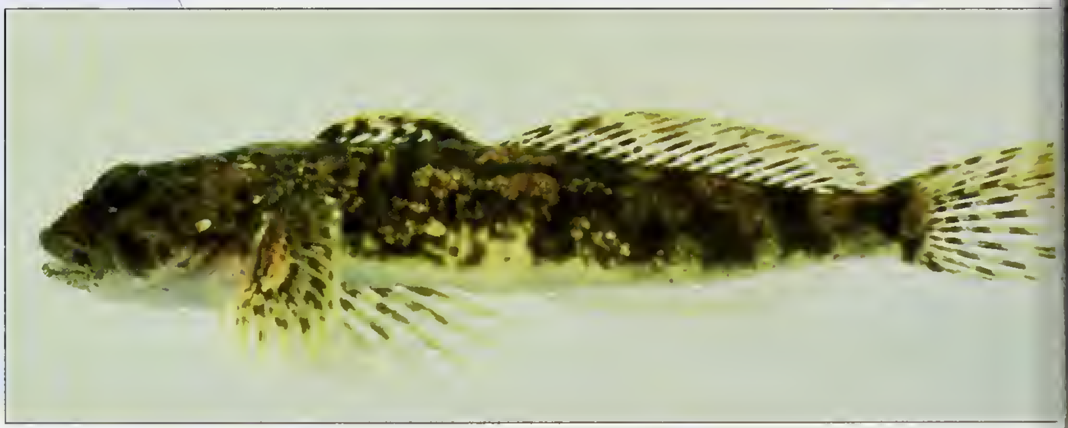


Figure 7. The percentage of each watershed or watershed group that is mapped as Critical Supporting Watershed.

The **Hudson River Watershed** drains the forests and rough terrain of the Taconic Mountains, and is where Massachusetts reaches its highest point on the summit of Mount Greylock. In Massachusetts, the Hudson Watershed is mostly made up of the Hoosic River Watershed, although portions of the Kinderhook and Bashbish River Watersheds extend into the state as well. Many cold headwater streams run down steep hillsides and into the Hoosic River, which flows north through Vermont before entering New York State and joining the Hudson River. Towns and farms are concentrated in the valleys and lowlands where shallow, hardwater ponds provide uncommon habitats for aquatic plants and animals.

The rare **Water Star-Grass** (*Heteranthera dubia*) lives in the shallow waters along the shores of hardwater ponds. The starry blooms of this usually inconspicuous plant often appear when the plant is stranded above the water line along the shore.

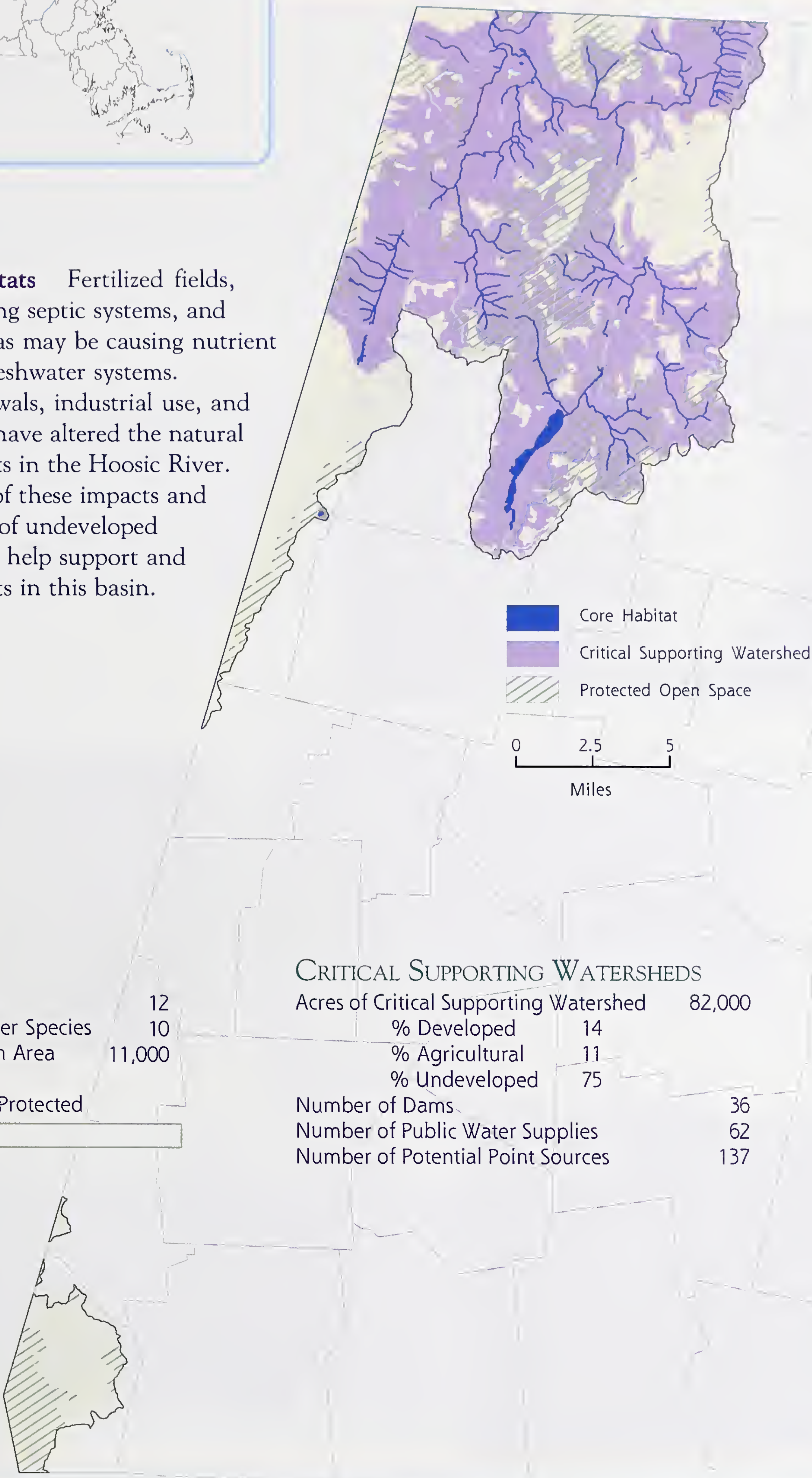
The mottled colors of the **Slimy Sculpin** (*Cottus cognatus*) help it hide amongst rocks and cobbles. In many of the small hill streams of western Massachusetts, the only native fish species present are Slimy Sculpin and Brook Trout. Both species rely on groundwater and forested riparian buffers to keep streams cold and well-oxygenated.



The **Appalachian Brook Crayfish** (*Cambarus bartonii*), a state-listed Species of Special Concern, is found only in the Hoosic River Watershed in Massachusetts. There are several populations in the small headwater streams that feed into the Hoosic River, but pollution in the river limits dispersal of the crayfish between these streams. Without genetic exchanges, these isolated populations are more vulnerable to local extinction.

Hudson

Protecting Core Habitats Fertilized fields, livestock manure, failing septic systems, and runoff from urban areas may be causing nutrient enrichment of some freshwater systems. Groundwater withdrawals, industrial use, and flood control projects have altered the natural flow cycles and habitats in the Hoosic River. Mitigating the effects of these impacts and the further protection of undeveloped headwater streams will help support and maintain Core Habitats in this basin.



Core Habitats

Number of Core Habitats	12
Number of Rare Freshwater Species	10
Acres of Adjacent Riparian Area	11,000

Amount of Riparian Area Protected

17% Protected

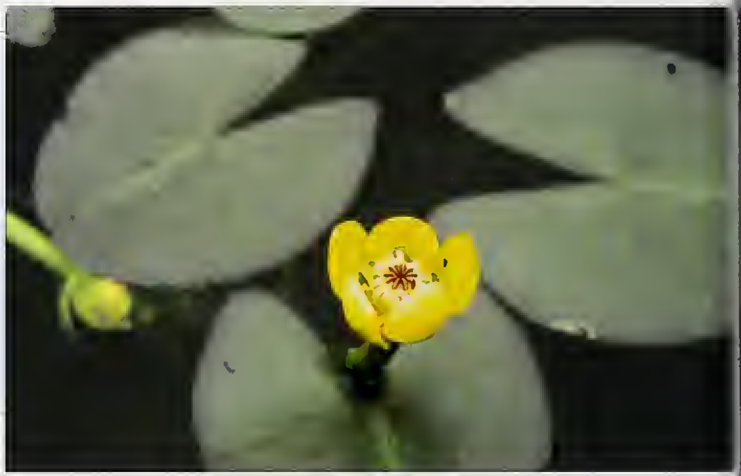
Critical Supporting Watersheds

Acres of Critical Supporting Watershed		82,000
% Developed	14	
% Agricultural	11	
% Undeveloped	75	
Number of Dams		36
Number of Public Water Supplies		62
Number of Potential Point Sources		137

The **Housatonic River** lies in a valley of marble and limestone bedrock that creates the unique water chemistry of its many hardwater streams, ponds, and wetlands. These distinctive freshwater habitats are uncommon in the rest of the state, and support a variety of specialized freshwater plants and invertebrates. The Housatonic River is relatively flat and meanders through several towns and agricultural lowlands and eventually empties into Long Island Sound. Most tributaries of the Housatonic River are fast flowing hill streams with cool, well-oxygenated waters that support coldwater fish communities.

The state-Endangered **Boreal Turret Snail** (*Valvata sincera*) is a tiny snail found in rooted vegetation around deep lakes. It reaches the southern edge of its range in Massachusetts and is more common to the north. Here, it is only known from three lakes across the state, all of which are surrounded by dense development. Unfortunately, it appears that these populations are in decline.

The **Tiny Cow-Lily** (*Nuphar microphylla*) is a small relative of our more common Yellow Water-lily (or Spatterdock). This state-Endangered floating-leaved perennial is mysteriously disappearing from the southern portion of its range, which once extended south to Pennsylvania. In Massachusetts, it was formerly known from a handful of lakes and ponds ranging as far east as North Reading, yet now only a single population can be found.



Marl Ponds are rare habitats associated with the marble and limestone bedrock of western Massachusetts. Calcium carbonate from the rocks and soil leaches into the water to create "hard water." During photosynthesis, aquatic plants growing in these waters produce marl, a white crust made up of calcium carbonate. Many marl ponds support beds of Stonewort (*Chara*), a large, plant-like green alga that provides homes for invertebrates such as the Boreal Turret Snail.

Housatonic

Protecting Core Habitats Dams, power generation, and municipal water use have changed natural river flows in this watershed. PCB contaminants from past electrical manufacturing operations have entered the aquatic food web. Sediment and nutrient-laden inputs from urban runoff, agricultural lands, and industrial discharges may degrade Core Habitats. Excessive plant growth by generalist and invasive plant species has the potential to edge out rare native aquatic plants. While there are several opportunities for land protection near some Core Habitats, the Core Habitats in developed areas will require careful management to protect their tremendous freshwater biodiversity.

Core Habitats

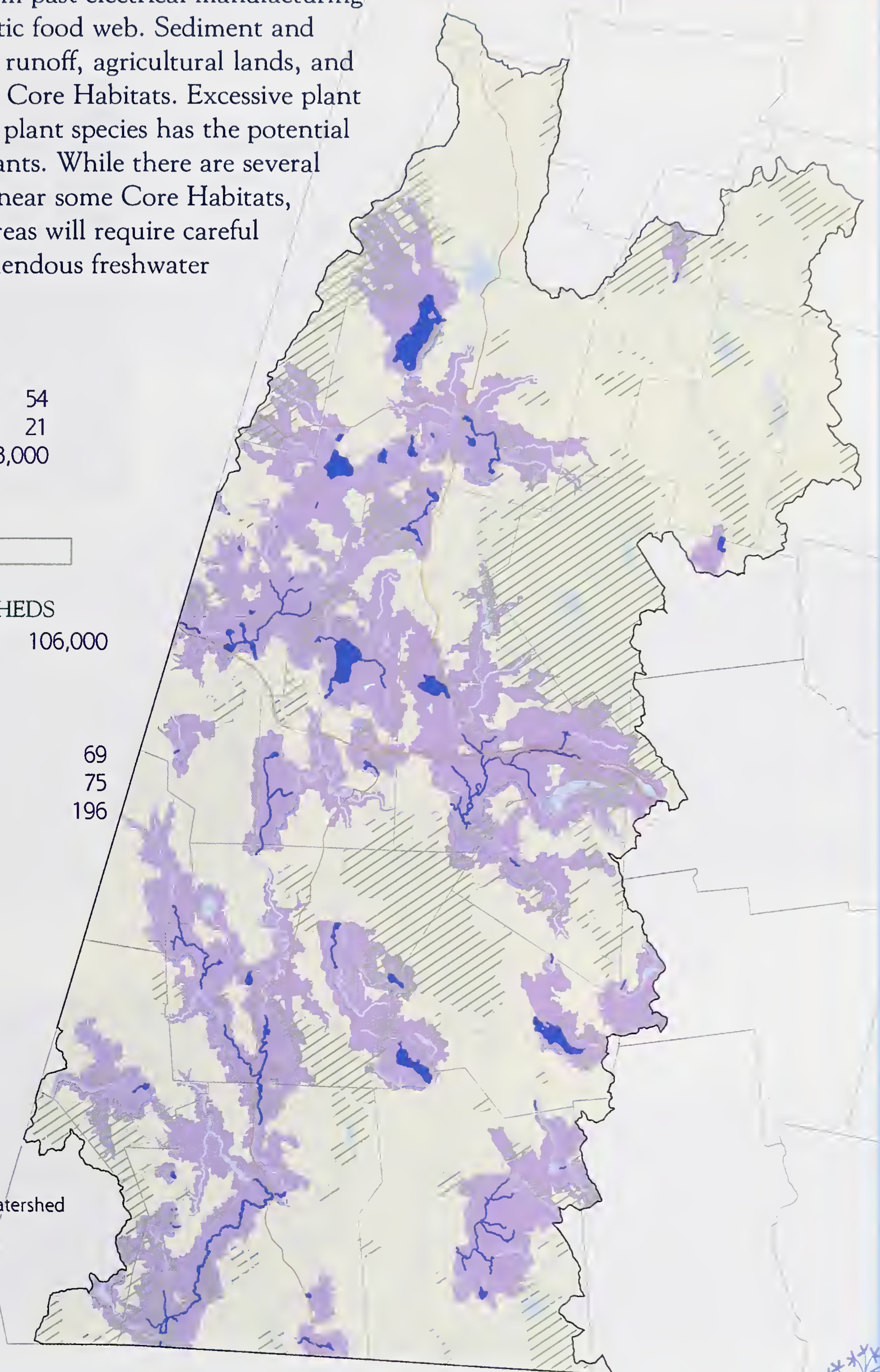
Number of Core Habitats	54
Number of Rare Freshwater Species	21
Acres of Adjacent Riparian Area	8,000

Amount of Riparian Area Protected

13% Protected

Critical Supporting Watersheds

Acres of Critical Supporting Watershed		106,000
% Developed	19	
% Agricultural	11	
% Undeveloped	70	
Number of Dams		69
Number of Public Water Supplies		75
Number of Potential Point Sources		196



The **Deerfield River** originates in Vermont and its tributary streams flow from the Berkshire Plateau down narrow, steep-sided valleys. Much of the remaining old growth forest in Massachusetts occurs along the steep, inaccessible slopes of some of the Deerfield River tributaries. Cool, high elevation ponds and rocky coldwater streams provide distinctive habitats for more boreal aquatic species. There are a variety of riverside plant communities along the Deerfield River and in the broadening floodplain as the river approaches the Connecticut River.

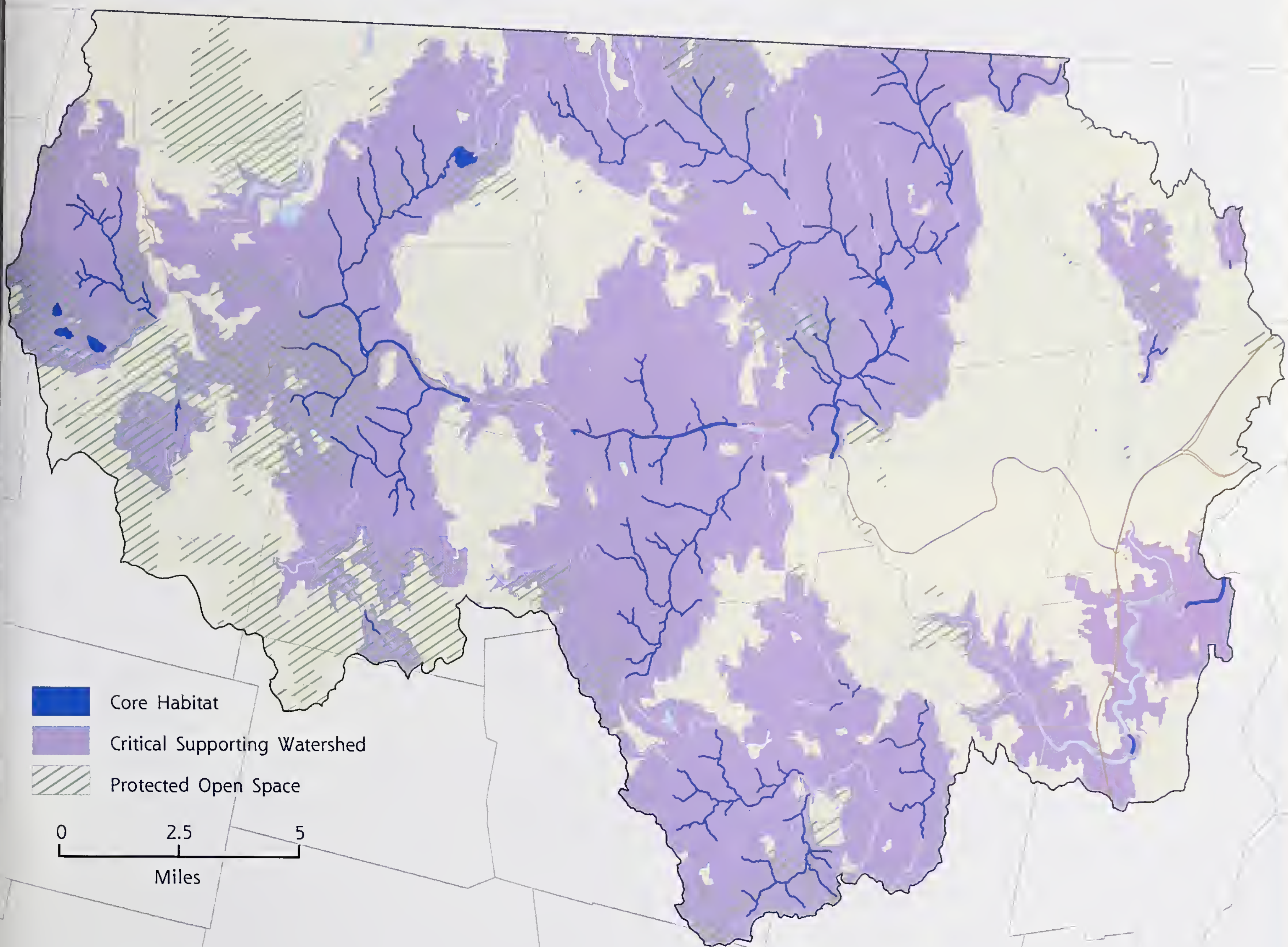
The state-Endangered **Northern Redbelly Dace** (*Phoxinus eos*) derives its name from the fact that its lower sides and belly turn bright red during spawning. This small minnow is only known from one river in Massachusetts. Separated from other northern New England populations, this fish could easily become locally extinct in Massachusetts without habitat protection.

Rivers and streams flow over a variety of **substrates**, from exposed bedrock, to fine silt and muck, to cobblestones and sands. Individual freshwater species often require certain types of substrate. For example, some insect larvae will be found clinging to the undersides of cobbles in fast-flowing streams. Meanwhile, some rare mussels need firm sand that is stabilized by a mix of gravel and cobbles. Dredging sediments out of the river or the deposition of excess silt from urban stormwater runoff changes the substrate type and may destroy the habitats of these species.

The torpedo-shaped **Longnose Sucker** (*Catostomus catostomus*) lives in cold, rocky, fast-flowing streams in the western basins of the state. This Massachusetts Species of Special Concern gets its name from its long nose that extends well beyond its mouth. The position of its mouth helps it root around the stream bottom for food like amphipods and black fly larvae.

DEERFIELD

Protecting Core Habitats Water diversion for upstream reservoirs and power plants causes extreme daily fluctuations in the flow of the Deerfield River. These diversions, combined with historic flood control projects, have constrained the natural flood cycles of the river and the movements of fish species. The runoff from roads, scattered pastures, and croplands has the potential to deliver excess sediments to nearby streams. Protecting the large natural areas and riparian forests in this watershed will help maintain the cold waters of its many Core Habitats.



CORE HABITATS

Number of Core Habitats	27
Number of Rare Freshwater Species	8
Acres of Adjacent Riparian Area	13,000

Amount of Riparian Area Protected

14% Protected

CRITICAL SUPPORTING WATERSHEDS

Acres of Critical Supporting Watershed		123,000
% Developed	10	
% Agricultural	8	
% Undeveloped	82	
Number of Dams		38
Number of Public Water Supplies		54
Number of Potential Point Sources		82

The **Westfield and Farmington Rivers** drain east and south through the rugged terrain of the Berkshire Plateau into the flatter Connecticut Valley. These watersheds are sparsely populated, with large areas of unfragmented forest. Mussels live in some of the moderately flowing portions of streams where there are firm sands and cobbles. In steeper, more rapid streams, ledge outcrops and cobble-bottoms provide specialized habitat for rare aquatic plants. Here, the fast-flowing cold water supports diverse communities of invertebrates, which in turn support coldwater fish communities.

The **Brook Floater** mussel (*Alasmidonta varicosa*), Endangered in Massachusetts, is found in rivers and streams with riffles and is thought to be sensitive to pollution, silt, and low levels of oxygen. Many of the remaining populations in Massachusetts are represented by a few aging individuals that show little evidence of reproduction.

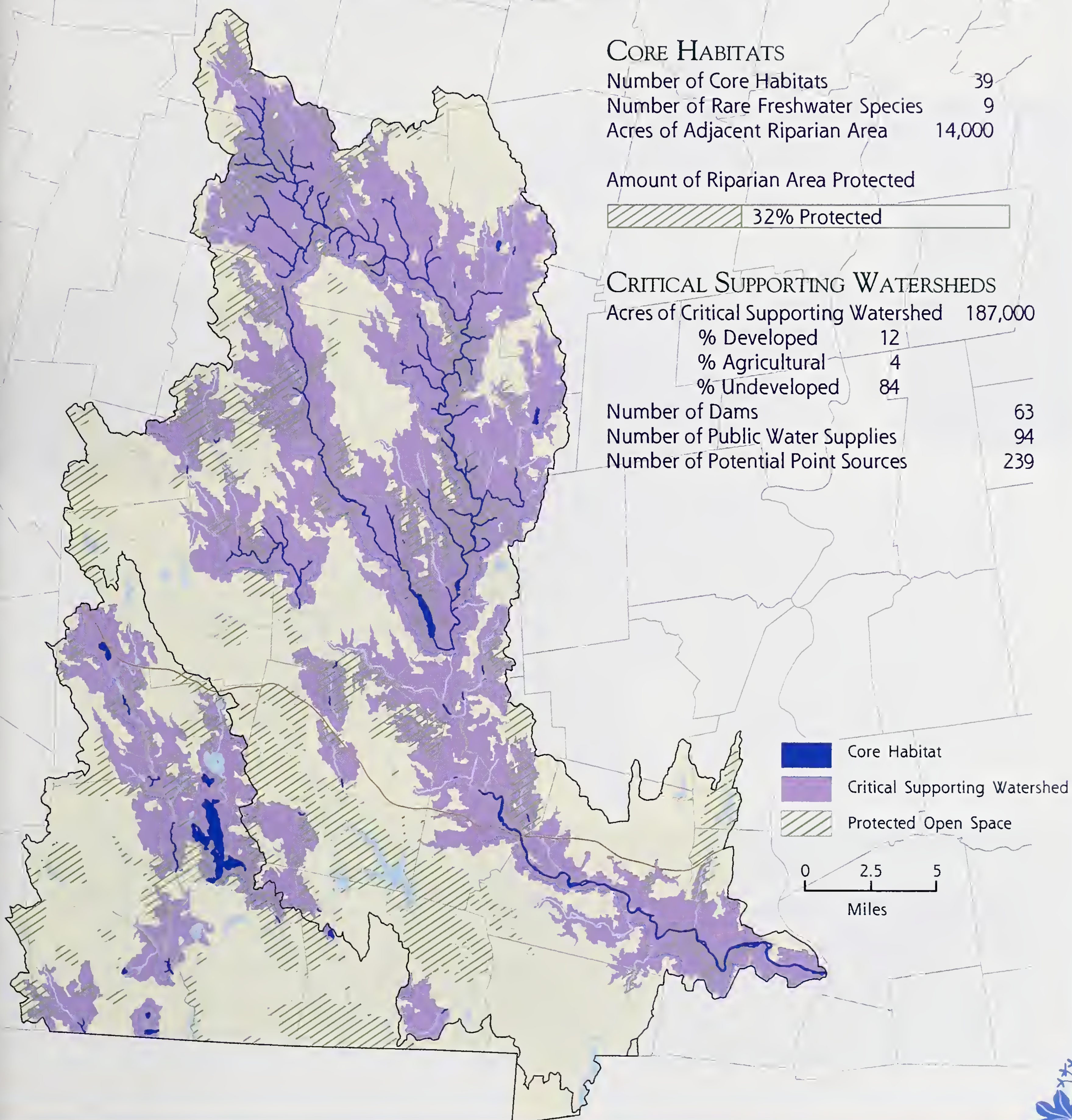
The state-Endangered **Lake Chub** (*Couesius plumbeus*) spawns in early spring and may migrate over six miles to reach spawning grounds. During the spawning season, the male turns orange around its mouth and fins. Despite its name, the Lake Chub in Massachusetts spawns in clear, cold, fast-flowing, rocky streams and rivers.

Fairy shrimp are delicate animals of vernal pools, the ephemeral water bodies formed in spring by snowmelt. These relatives of brine shrimp, or "sea monkeys," over-winter as eggs, hatch into larvae, grow into adults, and reproduce during the brief period in the spring when vernal pools are filled with water. The **Intricate Fairy Shrimp** *(Eubranchipus intricatus)*, a state-listed Species of Special Concern, could easily disappear from the Commonwealth without the preservation of its habitat.

Threadfoot *(Podostemum ceratophyllum)*, listed as Threatened in Massachusetts, is one of the only freshwater plant species adapted to live in swiftly-moving waters, such as river rapids. It uses fleshy pads to anchor itself to cobbles and rock ledges. Although able to withstand seemingly harsh natural conditions, this species is susceptible to the impacts of development such as siltation, water pollution, and drastic changes in water flow.

Westfield and Farmington

Protecting Core Habitats Large protected areas, particularly those along the three branches of the Westfield River, provide some of the most pristine Core Habitats in the state. There are many opportunities for additional land protection in these watersheds. Dams, reservoirs, and diversions for municipal water supply do affect parts of the Westfield and Farmington Rivers. Management of stormwater runoff from roads and developed areas can minimize the effects of sedimentation on Core Habitats.



Core Habitats

Number of Core Habitats	39
Number of Rare Freshwater Species	9
Acres of Adjacent Riparian Area	14,000

Amount of Riparian Area Protected

32% Protected

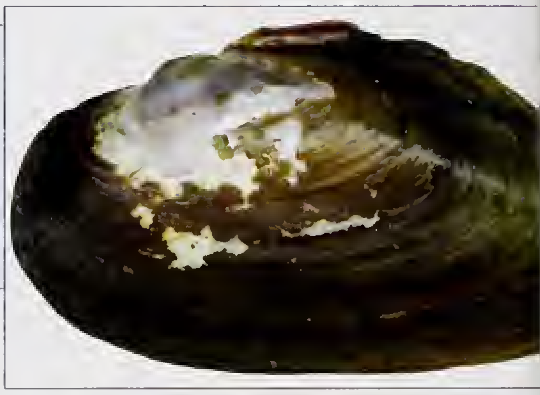
Critical Supporting Watersheds

Acres of Critical Supporting Watershed		187,000
% Developed	12	
% Agricultural	4	
% Undeveloped	84	
Number of Dams		63
Number of Public Water Supplies		94
Number of Potential Point Sources		239

The **Connecticut River** is the largest river in Massachusetts and has the largest drainage system in New England. It is a wide, deep river with wetlands and floodplain forests along its banks. In the broad river floodplain, natural changes in the course of the river have created oxbow ponds that provide critical habitats for many aquatic species. Some fish and mussel species that were historically present in the Connecticut River still persist, but their populations have been greatly reduced. The watershed crosses different terrain and geology to form a variety of aquatic habitats that support high biological diversity. For example, tributaries from the west carry higher pH waters down from the forests of the Berkshire Plateau. All of the state's twelve freshwater mussel species occur in this watershed, with the most diverse and abundant populations in the Connecticut River's main tributaries.

The **Connecticut River** stretches from the Canadian border down to Long Island Sound, providing 75 miles of unparalleled freshwater habitats in Massachusetts.

The **Dwarf Wedgemussel** *(Alasmidonta heterodon)* is a federally and state-Endangered species. In Massachusetts, it is only known from five tributaries to the Connecticut River, and only one of these rivers supports a viable and reproducing population.



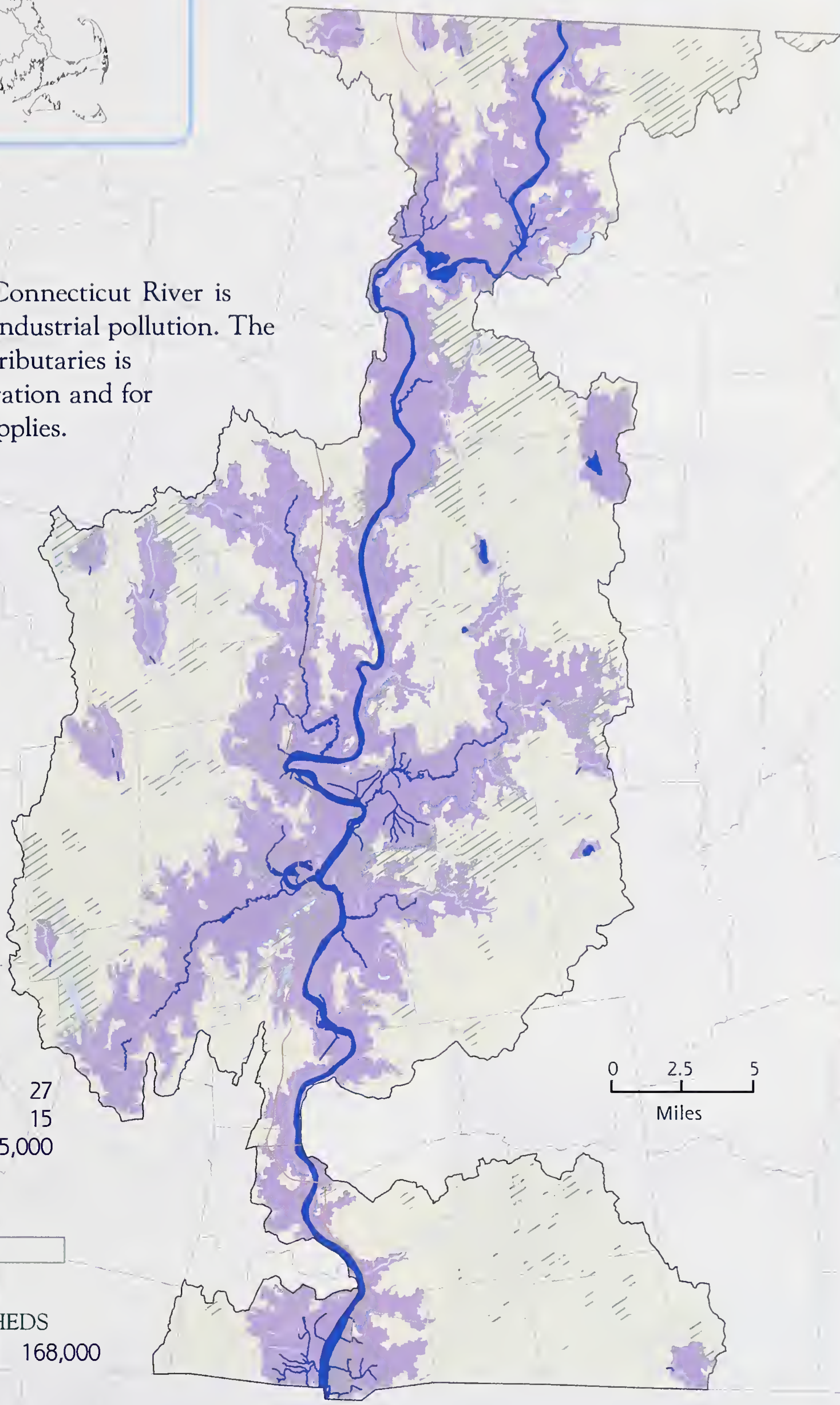
The smallest of the sturgeon species, the state- and federally-Endangered **Shortnose Sturgeon** *(Acipenser brevirostrum)* is in global decline. Habitat degradation or loss due to dams, bridge construction, channel dredging, and pollution are major threats to this fish.

Until recently, scientists were concerned that the state-Endangered **Yellow Lampmussel** *(Lampsilis cariosa)* could be locally extinct. This species is only known from the Connecticut River in Massachusetts, where scuba divers recently rediscovered more than 30 live animals at depths of up to 15 feet!

The **Eastern Silvery Minnow** *(Hybognathus regius)*, a state Species of Special Concern, lives in the shallow, vegetated oxbows, quiet pools, and lower tributaries of the Connecticut River. The decline of this minnow may be due to changes in the character of its backwater and spawning habitats from flow controls in the Connecticut River Watershed.

Connecticut

Protecting Core Habitats The Connecticut River is recovering from many decades of industrial pollution. The flow of the river and many of its tributaries is regulated by dams for power generation and for the creation of municipal water supplies. Stormwater runoff from fields, roads, and urban developments likely contributes to the salt, sediment, and nutrient loads of neighboring water bodies. Much work is needed to protect the forested riparian areas near Core Habitats, as well as to restore natural vegetation along the developed portions.



Core Habitats

Number of Core Habitats	27
Number of Rare Freshwater Species	15
Acres of Adjacent Riparian Area	15,000

Amount of Riparian Area Protected

10% Protected

Critical Supporting Watersheds

Acres of Critical Supporting Watershed		168,000
% Developed	26	
% Agricultural	16	
% Undeveloped	58	
Number of Dams		122
Number of Public Water Supplies		51
Number of Potential Point Sources		668

Core Habitat

Critical Supporting Watershed

Protected Open Space

The **Millers and Chicopee Rivers** drain west to the Connecticut River through a characteristic Massachusetts landscape of rolling hills underlain by acidic bedrock. The small streams that drain the uplands are naturally acidic from the bedrock's influence. Similarly, depressions in the terrain create scattered acidic, low nutrient ponds that are important for freshwater plants and invertebrates. Both rivers flow along a moderate slope with some extremely steep stretches. Many tributaries are cold, fast flowing streams with rocky substrates that provide good habitats for coldwater fishes and invertebrates dependent on oxygen-rich waters. The Chicopee Watershed contains a great diversity of river habitats that support one of the more diverse and healthy assemblages of mussels in the state. It is also home to the Quabbin Reservoir, the largest and deepest lake (albeit man-made) in Massachusetts, which supplies most of Greater Boston with drinking water.

The **Bridle Shiner** *(Notropis bifrenatus)*, a Species of Special Concern in Massachusetts, is a small minnow that only reaches a length of two inches. It lives in quiet waters around aquatic plants, and its schools swim in and out of the vegetation. In recent surveys in eastern Massachusetts, the Bridle Shiner was only found at one quarter of the sites where it was previously known.

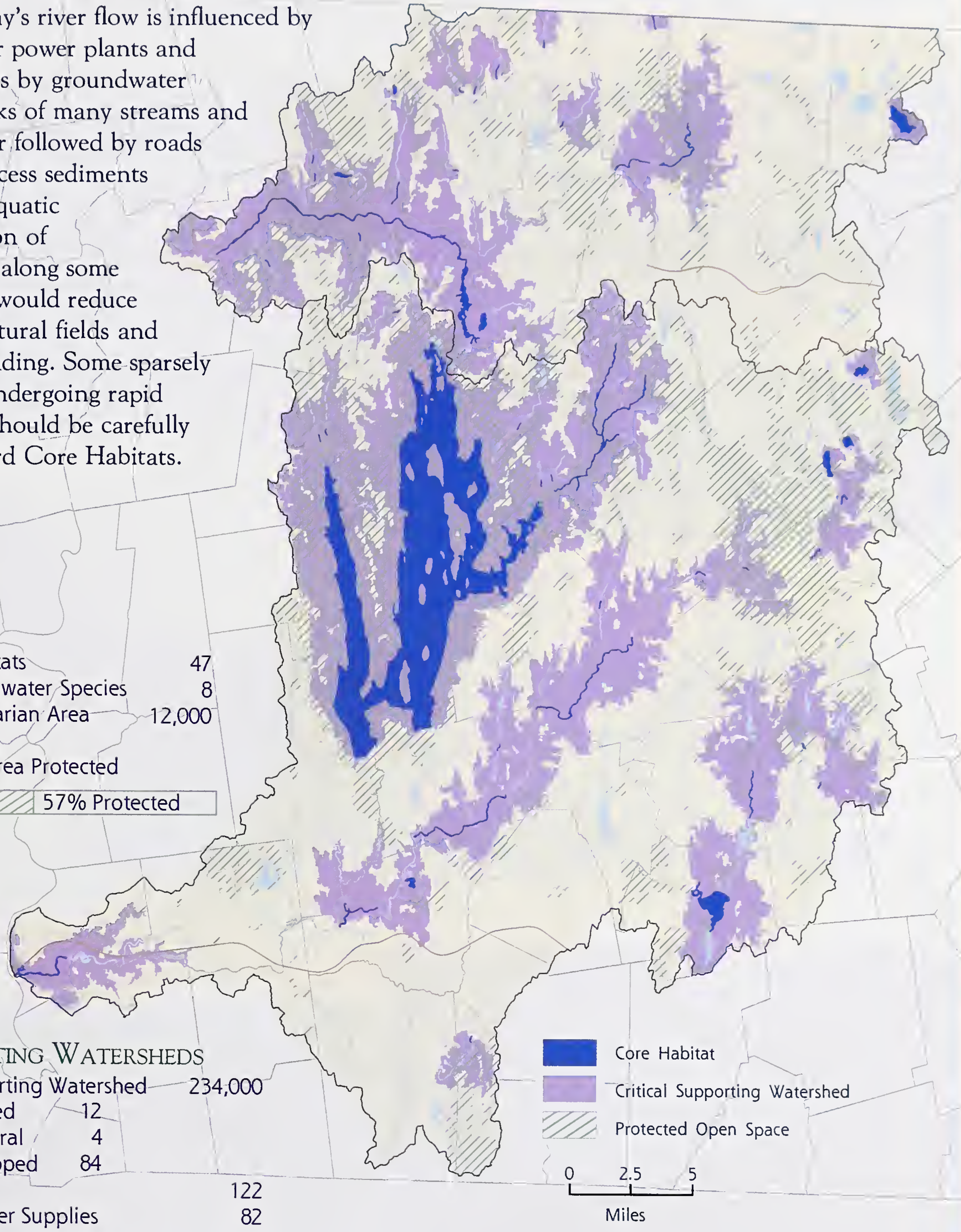
Despite its unflattering name, the rare **Algae-like Pondweed** *(Potamogeton confervoides)* is a graceful and delicate plant. Found only in sparsely vegetated, acidic, and nutrient-poor waters, its numbers in Massachusetts have diminished, likely due to increased nutrient inputs. This nutrient loading encourages a greater number of generalist plants that crowd out the Algae-like Pondweed.

The **Eastern Pearlshell** mussel *(Margaritifera margaritifera)* is the only representative of its family in Massachusetts. It differs from other Massachusetts mussel species in its preference for cool, clear streams that support its fish hosts. It can live over 100 years, making it the oldest living mussel, and possibly the longest living invertebrate known!

Freshwater plants are often considered a nuisance, a sentiment reflected in names such as "Pond-weed," "River-weed," and "Pickerel-weed." While some non-native freshwater plants are aggressive, monopolizing habitats once used by native plants, it is important to remember that **not all freshwater plants are weeds**. In pristine aquatic systems, native plants are an important component of natural communities. They provide habitat and nutrition for other species and they add oxygen to the water through photosynthesis.

Millers and Chicopee

Protecting Core Habitats Historic mills dot the banks of many of these rivers, reminding us of their working past. Today's river flow is influenced by water diversions for power plants and reservoirs, as well as by groundwater pumping. The banks of many streams and rivers are crossed or followed by roads that likely bring excess sediments and road salts to aquatic habitats. Restoration of riparian vegetation along some streams and rivers would reduce runoff from agricultural fields and enhance stream shading. Some sparsely settled towns are undergoing rapid development that should be carefully planned to safeguard Core Habitats.



Core Habitats

Number of Core Habitats	47
Number of Rare Freshwater Species	8
Acres of Adjacent Riparian Area	12,000

Amount of Riparian Area Protected

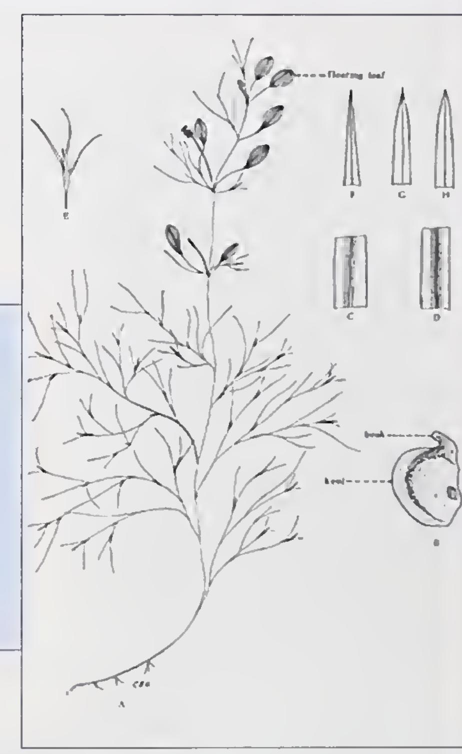
57% Protected

Critical Supporting Watersheds

Acres of Critical Supporting Watershed		234,000
% Developed	12	
% Agricultural	4	
% Undeveloped	84	
Number of Dams		122
Number of Public Water Supplies		82
Number of Potential Point Sources		289

The **Quinebaug, French, and Blackstone Rivers** are relatively flat and tame rivers typical of much of eastern Massachusetts. Parts of the gently rolling countryside have reverted from former farmland to second growth forest. Beaver dams are abundant on many of the tributaries of these rivers. Naturally acidic ponds provide habitat to aquatic plants of the region. The fish and invertebrate communities tend to be those of slow-moving warm water, although there are some cooler streams that support coldwater communities.

Shallow Beaver Ponds, wet meadows, marshes, and swamps are created when beavers build dams on streams. These productive wetland habitats provide nurseries for several fish species and many niches for aquatic invertebrates. The dams slow the flow of water, trapping silt and recharging underlying groundwater. Prior to European settlement, there were extensive beaver-created wetlands across North America, and as beaver populations rebound, some of these wetlands are returning.

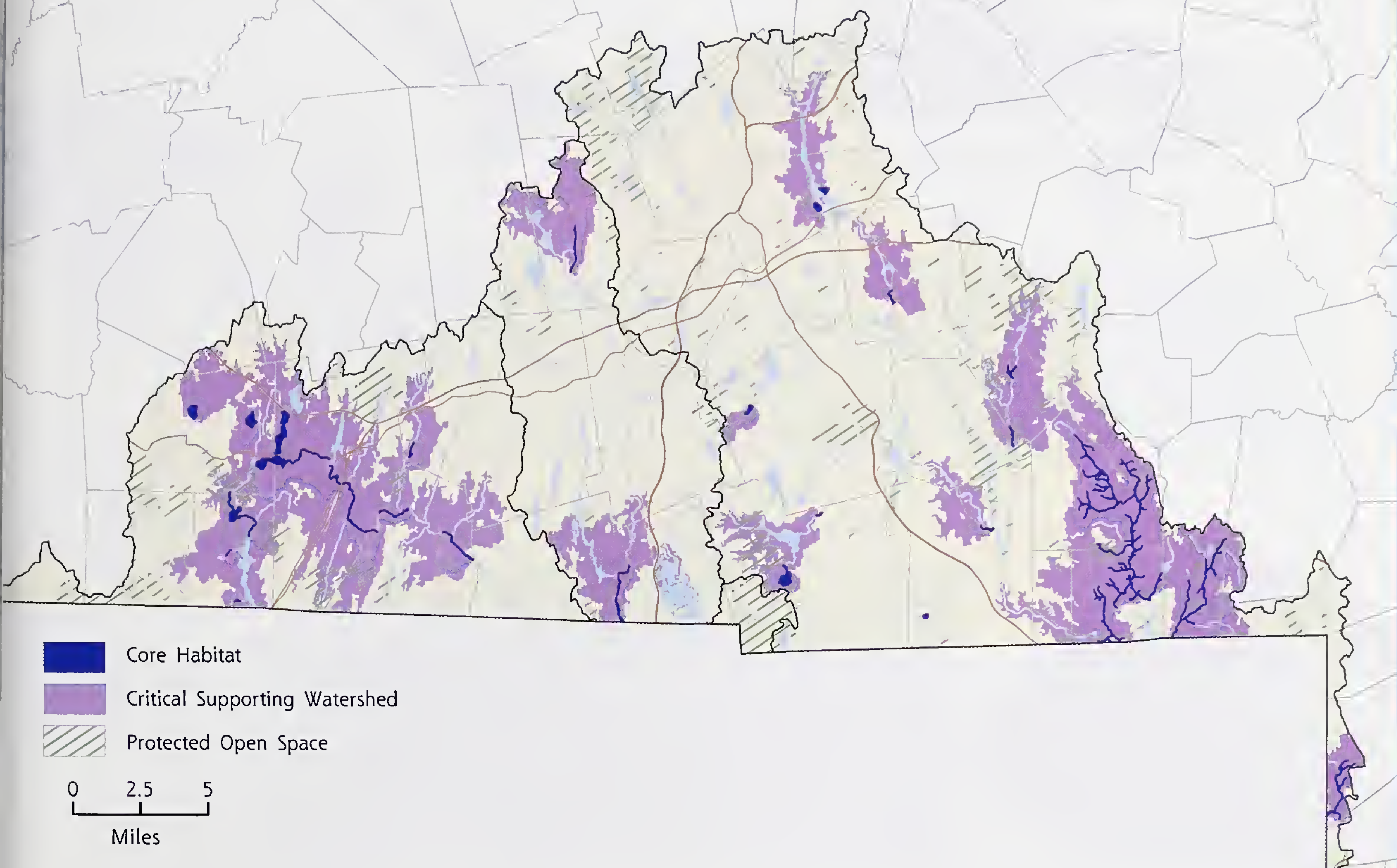


Until recently, botanists only knew of historic collections of **Vasey's Pond-weed** (*Potamogeton vaseyi*) in Massachusetts. However, recent field work in the Blackstone Watershed proved this plant still has a foothold in the Common-wealth. Sifting through preserved plant collections, botanical detective work uncovered more sites where this plant had been observed in the distant past. New searches in these water bodies resulted in the exciting rediscovery of several more populations of this state-Endangered species.

The state-Threatened **American Brook Lamprey** (*Lampetra appendix*) is a primitive fish with an interesting life cycle. The blind larva burrows into stream bottoms for four to five years and filter feeds using its funnel-like mouth. The larva then undergoes a metamorphosis to become an adult, developing eyes and a circular mouth with teeth. The adult uses this large mouth to move rocks and build a nest for spawning, as shown by the top fish in this picture.

Quinebaug, French and Blackstone

Protecting Core Habitats The Blackstone River was one of the first rivers in the country to become heavily industrialized. All three rivers have multiple flood control dams, reservoirs, and old mill ponds disrupting their natural flow cycles. There is substantial development in the Blackstone Watershed, and increasing development in the French and Quinebaug Watersheds. Protecting riparian vegetation and improving the management of dams, stormwater, and water use will help to sustain Core Habitats in these basins.



Core Habitats

Number of Core Habitats	28
Number of Rare Freshwater Species	8
Acres of Adjacent Riparian Area	6,000

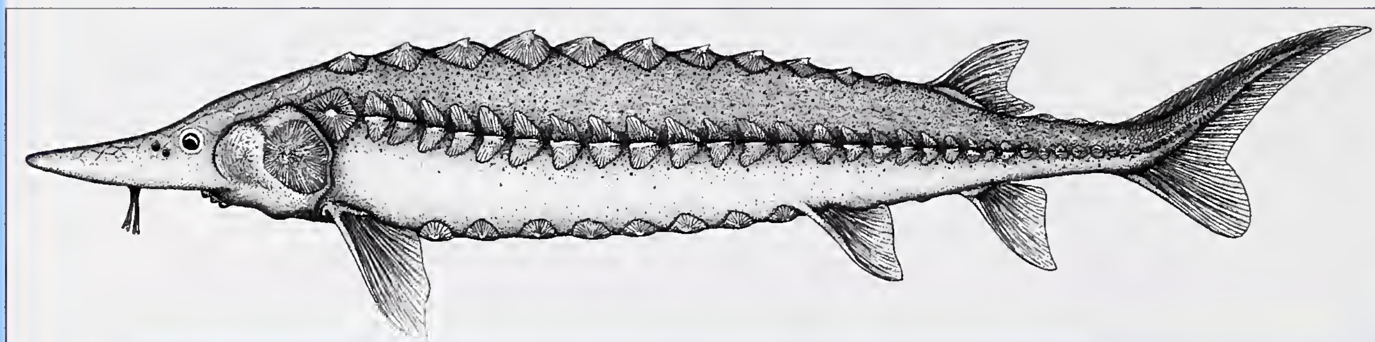
Amount of Riparian Area Protected

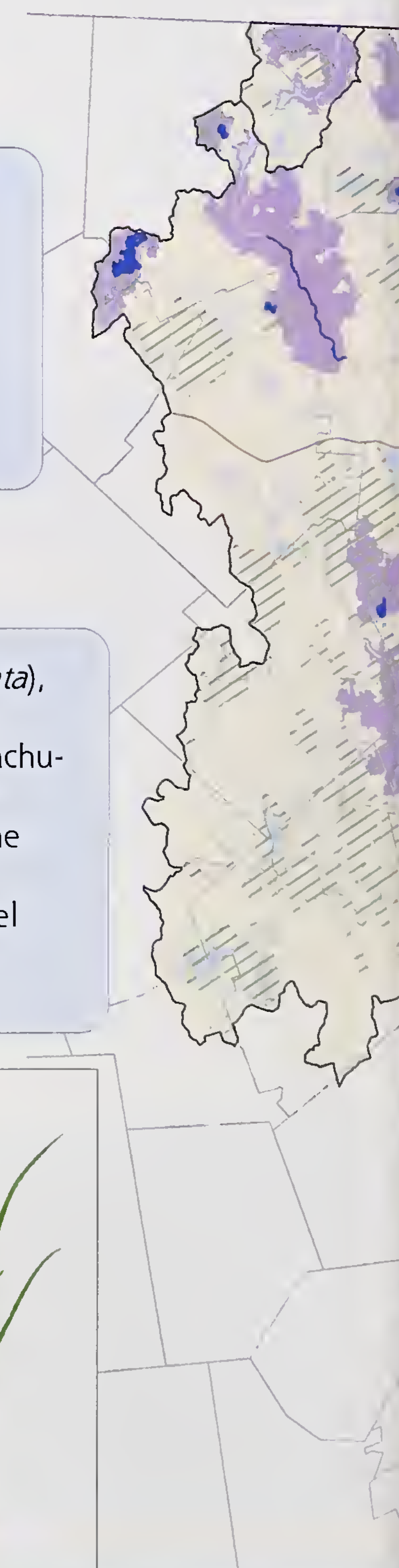
9% Protected

Critical Supporting Watersheds

Acres of Critical Supporting Watershed		99,000
% Developed	29	
% Agricultural	5	
% Undeveloped	66	
Number of Dams		148
Number of Public Water Supplies		88
Number of Potential Point Sources		359

The **Greater Merrimack River Watershed** is one of the largest watersheds in New England, with a quarter of its area in Massachusetts. The Nashua, Sudbury, Assabet, Concord, and Shawsheen Rivers all flow north to eventually join the Merrimack River. These rivers are slow moving and broad, and in their natural stretches are often lined with riverside meadows and marshes. All of these rivers support small patches of floodplain forests, which seasonally provide fish nurseries and habitat for emerging insects. Invertebrates tolerant of warmer, less oxygenated waters and soft sediments are predominant in many places. The Assabet River and the tributaries to the western Nashua River have slightly steeper slopes and tend to support fishes of cooler waters. Toward the coast, the estuary of the Merrimack River becomes key habitat for aquatic species.





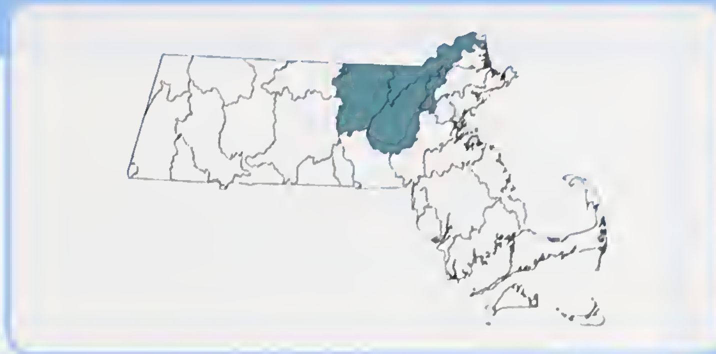
The state-Endangered **Atlantic Sturgeon** (*Acipenser oxyrinchus*) is a large prehistoric-looking fish that can exceed thirteen feet in length and weigh 800 pounds! This species uses coastal, estuarine, and freshwater habitats to complete its life cycle. Atlantic Sturgeon is a long-lived fish that can survive up to 60 years, and the female does not begin reproducing until it is at least ten years old.

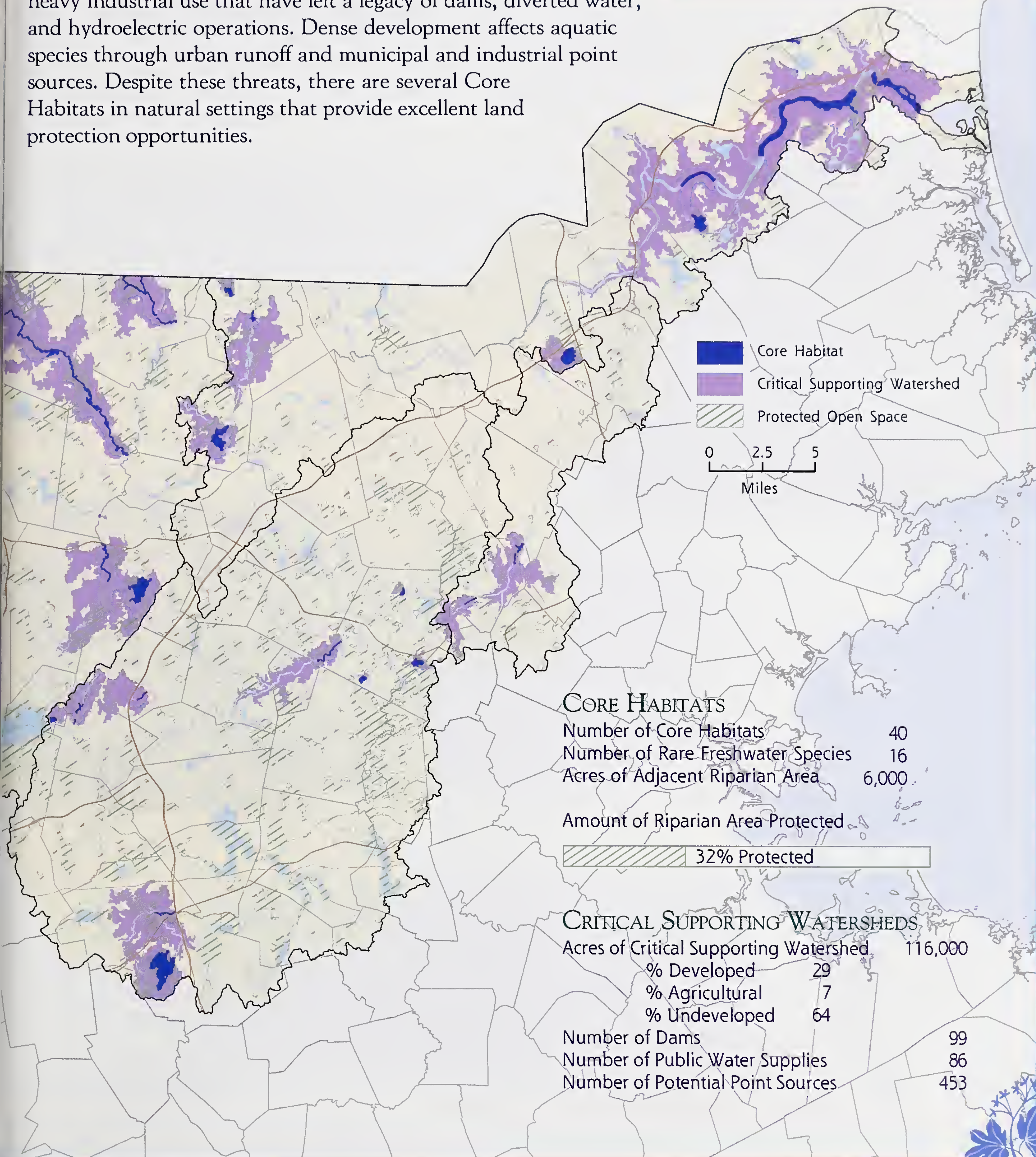
While the **Triangle Floater** mussel (*Alasmidonta undulata*), a state Species of Special Concern, occurs in lakes and ponds in other regions, it mainly lives in rivers in Massachusetts. Like most mussels in the state, the females brood their larvae over the winter before releasing them in the spring (see page 11). The larvae then attach to their required fish hosts, which for the Triangle Floater mussel may include large minnows like Fallfish and Common Shiner.

The state-Endangered **Lake Quillwort** (*Isoetes lacustris*) is currently known from only one pond in Massachusetts. Quillworts are primitive, submerged freshwater plants with thick, quill-like leaves rising from their base. This particular quillwort grows in pH-neutral to acidic waters. Remarkably, it has been collected from a depth of 25 feet, where limited amounts of sunlight can penetrate.

Greater Merrimack

Protecting Core Habitats These rivers share long histories of heavy industrial use that have left a legacy of dams, diverted water, and hydroelectric operations. Dense development affects aquatic species through urban runoff and municipal and industrial point sources. Despite these threats, there are several Core Habitats in natural settings that provide excellent land protection opportunities.





Core Habitats

Number of Core Habitats	40
Number of Rare Freshwater Species	16
Acres of Adjacent Riparian Area	6,000

Amount of Riparian Area Protected

32% Protected

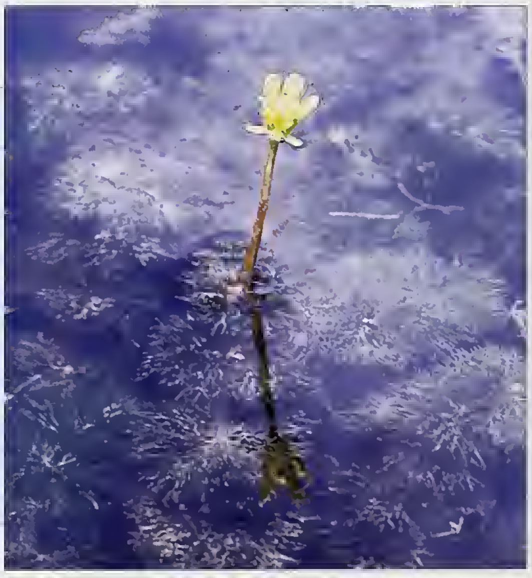
Critical Supporting Watersheds

Acres of Critical Supporting Watershed		116,000
% Developed	29	
% Agricultural	7	
% Undeveloped	64	
Number of Dams		99
Number of Public Water Supplies		86
Number of Potential Point Sources		453

The **Massachusetts Bay Watershed** contains many short coastal rivers with the exception of the meandering, 80 mile long Charles River. Rivers here have been heavily industrialized and surrounded by developed lands for centuries. The flat terrain creates extensive wetlands around the numerous small streams in the region. Small, scattered populations of mussels and rare aquatic plants persist in the best remaining habitats. The mouths of rivers farther away from the developed Boston area are important estuarine habitats, where salt and fresh waters mix. Many of these rivers are slow moving, soft-bottomed coastal rivers that support populations of sea-running fishes.

There is one population of the **Threespine Stickleback** (*Gasterosteus aculeatus*) that is state-listed as Threatened in Massachusetts. This population is the southernmost freshwater population known. The population also contains unusual individuals that have a low number of bony plates on their sides.

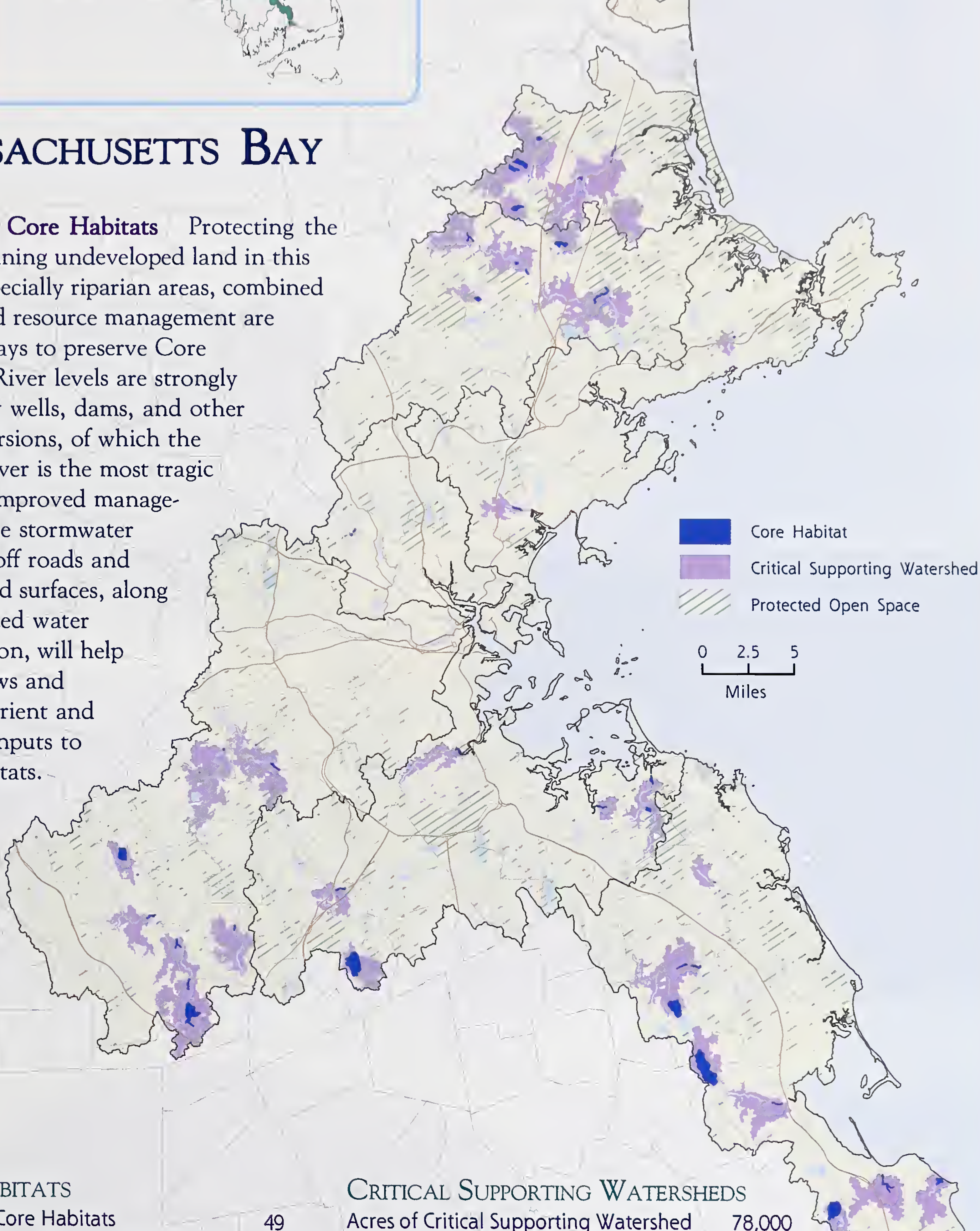
The rare **Water-Marigold** (*Megalodonta beckii*) is not truly a marigold, although its attractive, golden-yellow flowers emerging above the water may resemble one from a distance. More common in the past, this northern plant now appears to be declining throughout Massachusetts. The reasons for its apparent decline are unknown.



Alternate-Flowered Water-Milfoil (*Myriophyllum alterniflorum*) is a very rare species in Massachusetts. It is a smaller, native relative of the invasive exotic water-milfoils, Eurasian Water-Milfoil and Variable Water-Milfoil. Its common name is derived from the way the uppermost flowers are arranged in an alternate pattern along the stalk, unlike the opposite or whorled pattern of many other milfoils.

MASSACHUSETTS BAY

Protecting Core Habitats Protecting the little remaining undeveloped land in this region, especially riparian areas, combined with sound resource management are the best ways to preserve Core Habitats. River levels are strongly affected by wells, dams, and other water diversions, of which the Ipswich River is the most tragic example. Improved management of the stormwater that runs off roads and other paved surfaces, along with reduced water consumption, will help restore flows and reduce nutrient and sediment inputs to Core Habitats.



CORE HABITATS

Number of Core Habitats	49
Number of Rare Freshwater Species	16
Acres of Adjacent Riparian Area	3,000

Amount of Riparian Area Protected

16% Protected

CRITICAL SUPPORTING WATERSHEDS

Acres of Critical Supporting Watershed		78,000
% Developed	34	
% Agricultural	4	
% Undeveloped	62	
Number of Dams		73
Number of Public Water Supplies		80
Number of Potential Point Sources		179

The **Taunton-Narragansett Bay Watershed** is home to the Taunton, Ten Mile, and smaller coastal rivers that drain an area with low rolling hills and extensive wetlands. Most of the bedrock in this region is buried under glacial deposits that produce naturally acidic, low-nutrient soils and waters. A complex network of small streams winds through extensive swamps in the lowlands. Sea-running fishes return from the ocean to spawn and carry with them rich nutrients that nourish the freshwater systems. Several rare mussel species inhabit streambeds and ponds with sand and gravel bottoms. Local aquatic insect communities are adapted to the naturally occurring sandy and organic substrates. Small ponds and vernal pools provide habitats for rare aquatic plants.

Featherfoil (*Hottonia inflata*) is an uncommon plant with a very remarkable appearance. Its leaves are feather-like and it has small, white flowers on seemingly inflated stalks. This plant is rare in most surrounding states. Since Massachusetts has greater numbers of Featherfoil than our neighbors, we must safeguard our populations to avoid further declines in New England.

Anadromous fishes migrate from the ocean into freshwaters to spawn. In early spring, thousands of **Rainbow Smelt** (*Osmerus mordax*) can be seen swimming upstream toward their spawning habitats. These small, slender fish have been severely threatened by development that degraded their spawning sites and by dams that blocked their passage. Anadromous fishes are a key component of the freshwater biodiversity of Massachusetts and a lot of conservation work is underway to preserve this important resource. The Massachusetts Division of Marine Fisheries maintains considerable data on anadromous fishes.

The **Eastern Pondmussel** (*Ligumia nasuta*), a Massachusetts Species of Special Concern, possesses a long, narrow, and pointed shell that clearly distinguishes it from all other mussels in the state. While robust populations are found in the bottom sands of several lakes and ponds in southeastern Massachusetts, river populations usually contain only a few individual mussels.

Taunton-Narragansett Bay

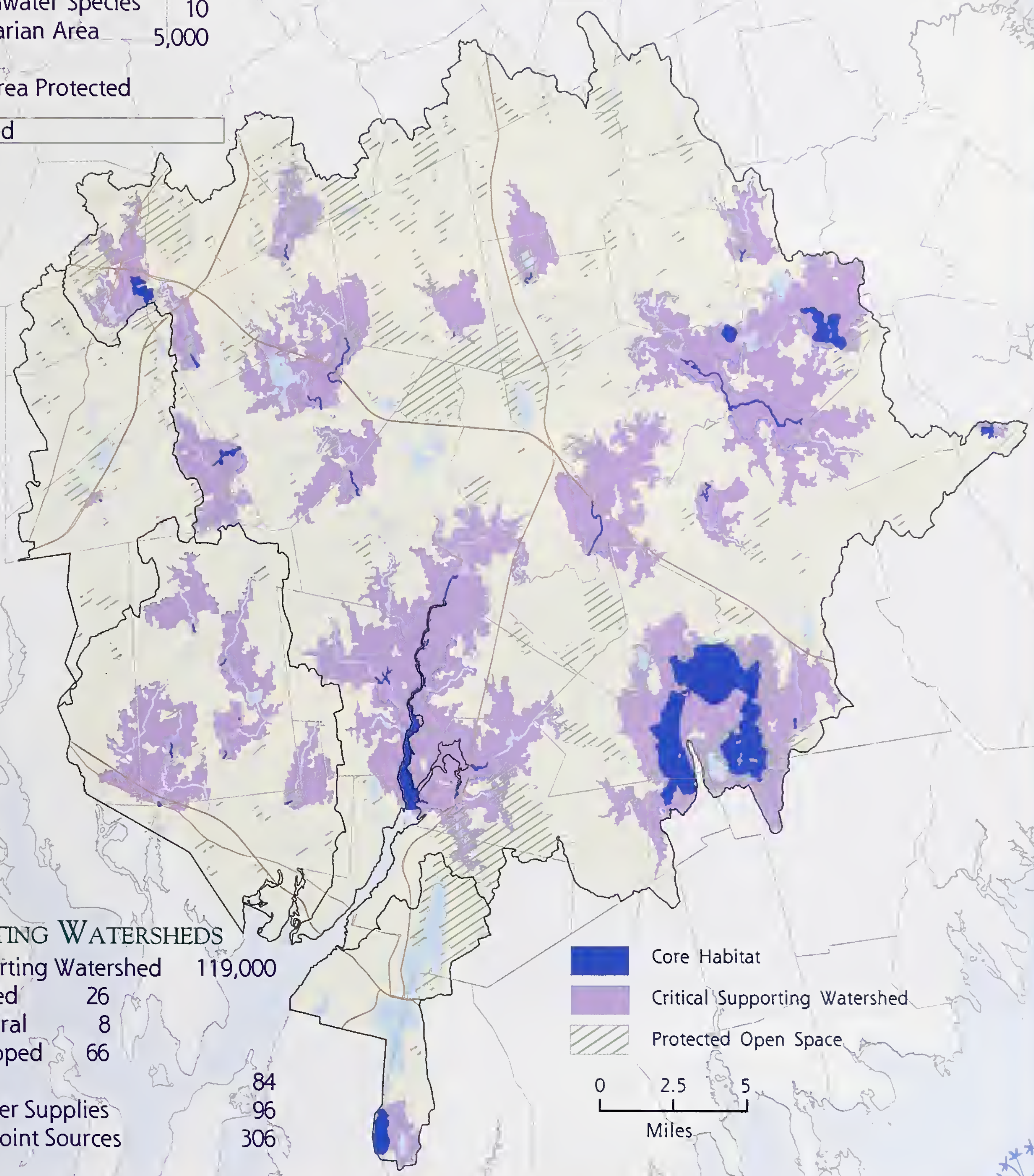
Protecting Core Habitats The flow of water is affected by channel straightening, groundwater withdrawals, and water diversions for cranberry bog agriculture. Urban and suburban developments near Core Habitats require careful management to reduce nonpoint source sediment and nutrient threats. Remaining natural riparian areas are the highest priority for land protection.

Core Habitats

Number of Core Habitats	33
Number of Rare Freshwater Species	10
Acres of Adjacent Riparian Area	5,000

Amount of Riparian Area Protected

16% Protected



Critical Supporting Watersheds

Acres of Critical Supporting Watershed	119,000
% Developed	26
% Agricultural	8
% Undeveloped	66
Number of Dams	84
Number of Public Water Supplies	96
Number of Potential Point Sources	306

The watersheds of **Buzzards Bay, Cape Cod, and the Islands** lie largely within the sandy Atlantic Coastal Plain. Many kettlehole ponds dot the landscape, and are naturally acidic and low in nutrients. These important habitats are home to some freshwater mussels, other invertebrates, and several rare aquatic plants. The slow-moving rivers and streams flow directly to the ocean, which has a moderating influence leading to a milder climate and the presence of more southern species than the rest of the state. The rivers, streams, and ponds are fed primarily by groundwater that moves easily through the sandy soils. Sea-running fishes return to several of the accessible streams in order to spawn.

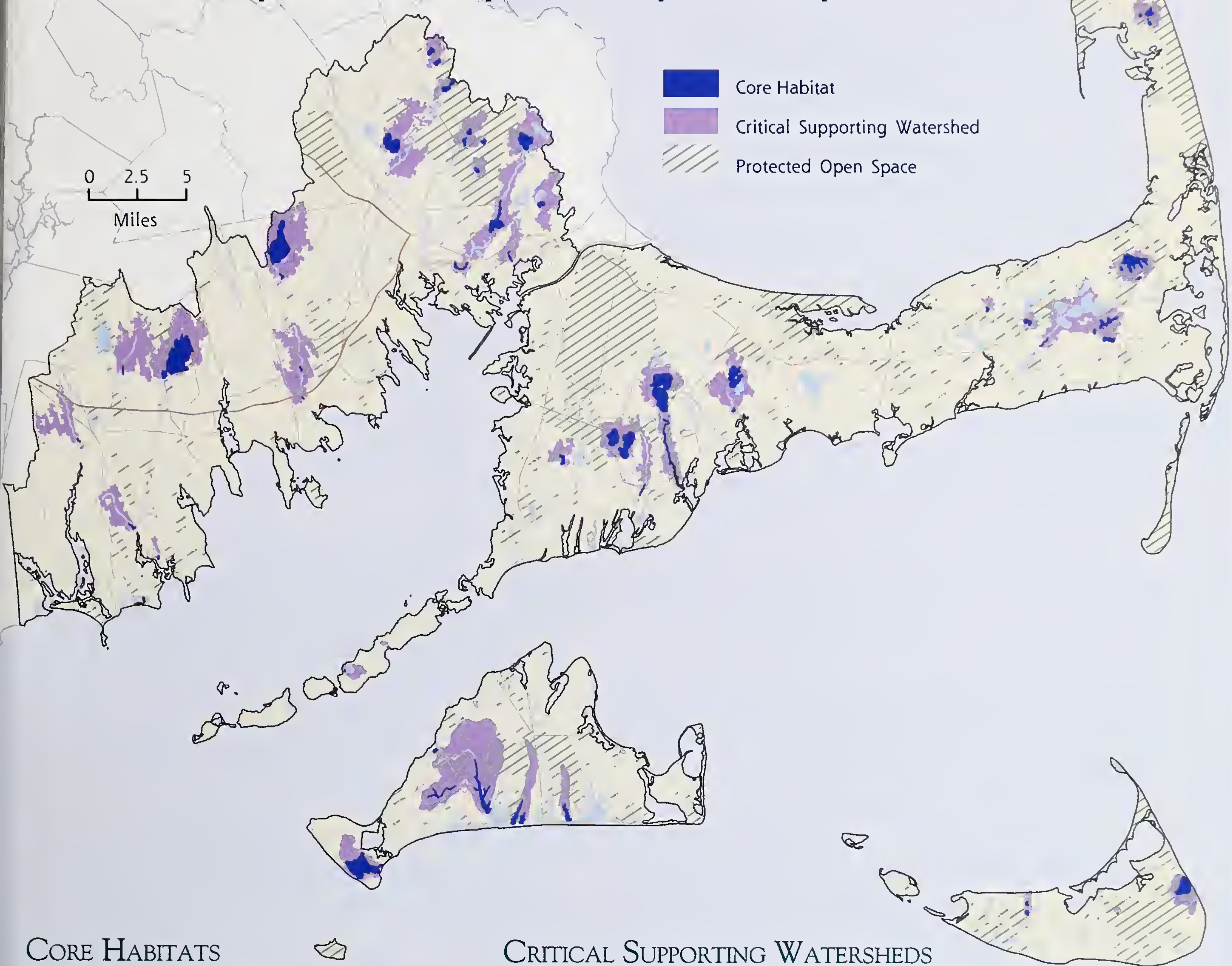
The **Tidewater Mucket** mussel *(Ligumia ochracea)*, a Massachusetts Species of Special Concern, is found in the sandy substrates of coastal lakes and ponds. Like most mussels, this species requires an outside host during its larval stage (see page 11). Since the Tidewater Mucket is usually found in water bodies close to the ocean, its larvae probably use sea-running fishes as fish hosts.

Coastal Plain Ponds are shallow, naturally acidic, groundwater-fed ponds with seasonally fluctuating water levels. These ponds have a distinct plant community along the shoreline with many rare upland and aquatic plants. They are also home to several species of rare dragonflies and damselflies. The natural cycles of high and low water levels are often threatened by public water supply wells that pump out groundwater and reduce groundwater inflows to ponds. Nutrient input from surrounding development, which leads to algal blooms and subsequent low-oxygen conditions, is another threat to the species living in Coastal Plain Ponds.

The rare purple-flowered **Resupinate Bladderwort** *(Utricularia resupinata)* is an elusive plant of sandy kettle ponds. Primarily found along the Coastal Plain, it flowers only during periods of extremely low water. Its delicate and inconspicuous stems can easily be overlooked. Like all bladderworts, this plant is carnivorous and captures small insects and other invertebrates in its pouch-like "bladders."

Buzzards Bay, Cape Cod, and the Islands

Protecting Core Habitats Although many streams have the remains of old mills, there is little industry found along them today. The area is facing enormous demand for housing, which increases groundwater withdrawals and has the potential to divert water away from Core Habitats. Increasing the amount of protected open space near Core Habitats should help reduce water consumption and other nonpoint source impacts of development.



Core Habitats

Number of Core Habitats	72
Number of Rare Freshwater Species	14
Acres of Adjacent Riparian Area	6,000

Amount of Riparian Area Protected

36% Protected

Critical Supporting Watersheds

Acres of Critical Supporting Watershed		66,000
% Developed	23	
% Agricultural	5	
% Undeveloped	72	
Number of Dams		46
Number of Public Water Supplies		90
Number of Potential Point Sources		49

Suggested Reading

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Glossary

Aquatic species – the plants and animals that spend all or a substantial portion of their life cycle completely underwater.

Biodiversity, *or* **Biological diversity** – the full range of variety and variability of life. The term encompasses ecosystem, community, species, and genetic diversity.

Critical Supporting Watershed – the more immediate portion of a Core Habitat's watershed, representing the portion of the watershed with the greatest potential to sustain or degrade the Core Habitat. The boundaries of the Critical Supporting Watershed were drawn using a GIS-based computer model.

Exemplary aquatic habitat – a water body that is presumed to support intact freshwater communities based on one or more indications from biological data, habitat evaluations, water chemistry analyses, and natural landscape settings.

Groundwater – water held within the interconnected openings of saturated rock or surficial deposits beneath the land surface, similar to the way in which water is held within a sponge. Groundwater supplies wells and springs, and can supply water to, or draw water from, neighboring water bodies.

Habitat – the area and resources used by a plant or animal, defined by species-specific requirements within the physical, chemical, and biological environment.

Hard water – water with high levels of dissolved minerals, such as calcium carbonate. Hard water is created when water flows through and picks up minerals from the soil and rocks in areas underlain by marble and limestone bedrock.

Kettlehole ponds – ponds formed at the end of the last Ice Age when glaciers receded, leaving behind massive ice blocks embedded in the barren terrain. As the climate warmed, the remnant ice blocks melted, creating large, kettle-shaped hollows in the landscape that filled with water to form ponds.

Living Waters Core Habitat – a lake, pond, river or stream that provides habitat for a rare species population, or that is known to be an exemplary aquatic habitat in Massachusetts.

Nonpoint source pollution – pollution that originates from many diffuse sources. Nonpoint source pollution is caused by air or water that picks up pollutants across the landscape, carries them over and through the ground, and concentrates them in water bodies. Some of the pollutants that contribute to nonpoint source pollution include: fertilizers, herbicides, insecticides from lawns and farms; oils, greases, and toxic chemicals from cars, roads and industries; sediments from construction sites, agricultural fields, and eroded stream banks; and bacteria and nutrients from livestock, pet wastes, and faulty septic systems.

Nutrient enrichment, *or* **Eutrophication** – the process by which a body of water becomes overly enriched in dissolved nutrients (mostly phosphorus and nitrogen) that stimulate the growth of aquatic plant life usually resulting in the depletion of dissolved oxygen.

Point source pollution – pollution releases from industrial and municipal pipes, ditches, and other discrete sources.

Population – a group of actually or potentially inter-breeding individuals of the same species located in a particular time and place.

Public water supplies – surface and groundwater sources that are used by the public for drinking water.

Riparian area – an area of land that borders a water body.

Runoff – the portion of precipitation on land that ultimately reaches water bodies, often with dissolved or suspended material. Runoff reaches receiving waters gradually through the porous and varied terrain of natural landscapes, but it runs quickly off the impervious surfaces of urban landscapes, like roads, parking lots, and buildings.

State-listed rare species – species protected under the Massachusetts Endangered Species Act, M.G.L. c.131A, and its implementing regulations, 321 CMR 10.00. Rare species are listed as Endangered (the most imperiled), Threatened, or Species of Special Concern.

Stormwater – runoff from land and impervious areas such as paved streets, parking lots, and building rooftops during rainfall and snow events. Stormwater often contains pollutants in quantities that could adversely affect water quality and species habitats.

Watershed – an area of land, defined by its topography, within which all water flows to a common point such as a pond or a river.

Photo and Illustration Credits

Illustrations:
Dave DiAngelis and **Dana Dunn:** page 9. **Barre Hellquist:** page 38 (middle). **Ethan Nedeau:** pages 36 (middle), 40 (top and bottom), 42 (bottom), 48 (bottom). **Neves and Pels:** page 11 (top).

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Carrie Banks/Massachusetts Riverways Program: page 23 (bottom). **Matt Burne**/NHESP: front cover (bottom), page 26 (bottom). **Bill Byrne**/Massachusetts Division of Fisheries and Wildlife: pages 6, 12, 15 (bottom). **Donald Cameron**/Maine Natural Areas Program: page 44 (top). **Brent Cooke**/Royal British Columbian Museum: page 42 (top). **Frances Garretson**/NHESP: page 15 (top). **Ethan Gordon:** pages 32 (top). **Karston Hartel**: page 36 (top). **Alexander Huryn** and **Phillip Wick**: page 11 (bottom right). **Keith Jackson**: page 30 (bottom). **Leo Kenney**: page 32 (bottom). **Bob Michelson:** page 44 (middle). **NHESP:** pages 7 (bottom), 28 (top). **Ethan Nedeau:** pages 34 (middle), 40 (middle), 44 (bottom), 46 (top). **Massachusetts Division of Fisheries and Wildlife:** page 23 (top). **Don Padgett:** pages 7 (top) and 28 (middle). **Pam Polloni:** page 46 (bottom right). **Paul Rezendes:** front cover, back cover, pages 2, 5, 16, 22, 36 (bottom), 38 (top), 46 (left). **Fred SaintOurs:** page 8. **John F. Scarola**/New Hampshire Fish and Game Dept.: pages 26 (middle), 34 (bottom). **Konrad Schmidt**: front cover (top), pages 30 (top), 32 (middle), 38 (bottom). **Joanne Singfield/NHESP:** page 28 (bottom). **Paul Somers**/NHESP: pages 9 (bottom), 26 (top). Bruce Sorrie/NHESP: pages 30 (middle), 42 (middle). **Chloe Stuart**/NHESP: page 34 (top). **L. Wagner**/Massachusetts Audubon: page 13. **Barry Wicklow:** page 11 (bottom left).

Afterword

Although freshwater species are easily overlooked, they include some of the most imperiled in Massachusetts. To ensure their survival, it is imperative that we continue to address their conservation needs. The Living Waters conservation plan provides an important conservation tool for aquatic biodiversity by identifying specific "Core Habitats" in rivers, streams, lakes, and ponds based on scientific information on freshwater species and their habitats. The Living Waters concept of the "Critical Supporting Watershed" challenges us to transcend political boundaries and consider a watershed-based approach to aquatic conservation. Within these areas, aquatic species can, and should, be protected through both traditional land conservation measures and through management practices tailored to restore water flow and quality, and thus their habitat.

Two years after the release of Natural Heritage's *BioMap: Guiding Land Conservation for Biodiversity in Massachusetts*, BioMap is being used by many individuals, conservation organizations, towns, and state agencies to guide land protection. We hope that Living Waters will be as useful as the BioMap, and that it will help incorporate freshwater biodiversity considerations into land conservation strategies and resource management practices. We also hope that Living Waters will raise the profile of Massachusetts' freshwater species and inspire more scientific work to further understand this important component of our native biodiversity.

Massachusetts Division of Fisheries & Wildlife

Natural Heritage
& Endangered Species
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